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ANGIOGRAPHY IN ACUTE SUPERIOR MESENTERIC ARTERIAL INSUFFICIENCY

by

TRYGVE AAKHUS and GEORG BRABRAND

In an effort to reduce the high mortality in acute superior mesenteric vascular insufficiency an earlier diagnosis would seem to be a major contribution The initial clinical signs are usually not conclusive and laboratory methods have as yet yielded no definite contribution to the recognition of the condition (BRAUN et coll 1960 SHERMAN 1962 MAVOR et coll 1962) Laparotomy is generally the ultimate diagnostic procedure usually after several hours of observation and after intractable damage has supervened

Conventional roentgen examination may be decisive particularly in the advanced stages when retention of fluid and gas in the lower ileum and right half of the large bowel edematous thickening of the bowel wall or even signs of peritonitis may be highly suggestive (FRIMANN DAHL 1950 HESSEN 1955) In the early stages however, no abnormal signs or only slight changes to suggest peritoneal irritation may appear in the conventional films

As the essential feature in this condition is circulatory insufficiency angiography seems to be a reasonable approach in the establishment of an early

From the Roentgen Department (Director Prof J Frimann Dahl) and the Department of Pathology (Director Prof K Arnesen) Ullevål Hospital Oslo Norway This work was reported upon at the Meeting of the Scand Society of Medical Radiology at Helsinki 1964 Submitted for publication 29 March 1965





Fig 1   Fig 2

Fig 1 A ter al pha e of no mal selective superior mes nteric ang ography The cal b r of the main br nches from the art ry should be no ed also the finer b a iches are clearly visible

Fig 5 lective ang ography n a female aged 70 Thrombos s of superior mesenteric artery (arrow) marked nar ov ing of branches prox mal to occlusion ao t c contrast reflux partly due to reduced mesente ic blood flow

sources of emboli in the chambers of the heart and for old or recent infarc tions in organs Roentgen examination of the specimen was performed in some instances following injection of a Micropaque dispersion into the superior mesenteric artery and subsequently into the veins via the splenic vein

Results

The appearances of the conventional films were usually compatible with mesenteric thrombosis although never conclusive The presence of small fluid levels in the small and large intestine most often indicated a diagnosis of peritoneal irritation In one instance the dominating finding in the convention al films was an extremely distended large bowel

The arterial phase of a normal selective superior mesenteric angiography is shown in Fig 1

diagnosis The value of aortography in intestinal angina has been stressed (MAVOR et coll 1962, SULLIVAN 1963, FRY 1963), but no report seems to have appeared on the value of angiography in cases of acute mesenteric vascular insufficiency

Angiography has lately come into use in cases of acute abdominal disease in this department and the angiographic findings in seven patients suffering from acute superior mesenteric arterial insufficiency leading to bowel gangrene are presented in this paper

Material This consisted of 5 females and 2 males, ranging in age from 46 to 79, all with long standing cardiac disorders Six patients had auricular fibrillation and four patients had definite signs of cardiac failure at the time of admission All the patients were on digitalis, and in one patient evidence of digitalis overdosage was detected by ECG

The duration of the acute symptoms prior to admission varied from 12 hours to 3 days Epigastric or diffuse abdominal pain and vomiting were the usual complaints On admission all the patients were severely ill with cold and clammy skin, however, in all except one the blood pressure was normal or raised

'Mesenteric thrombosis' was suggested clinically in all the subjects but in none was the diagnosis definitely established prior to the roentgen examination

Method Angiography was performed 1 to 5 days after the onset of symptoms, usually a few hours after admission Percutaneous transfemoral aortography was performed in the anteroposterior projection to localize the level of the origin of the superior mesenteric artery and demonstrate the blood flow in this artery in comparison with the other aortic branches Lateral films were obtained to demonstrate the state of the first segment of the arteries arising anteriorly from the abdominal aorta Selective angiography was performed for a more detailed study of the superior mesenteric arterial tree Thirty milliliters of Isopaque 60 % were used for aortography and 20 ml Isopaque 45 % for the selective angiographic examination The whole examination was usually accomplished in the course of 1 to 1 1/2 hours

Most patients were submitted to operation a few hours after angiography and notes were made of the arterial pulsations in the mesentery and the appearance of the bowel

All the patients who died were examined post mortem The gastrointestinal tract was closely examined for circulatory changes and the vessels searched for atherosclerosis, thrombi or emboli Particular care was also applied to find

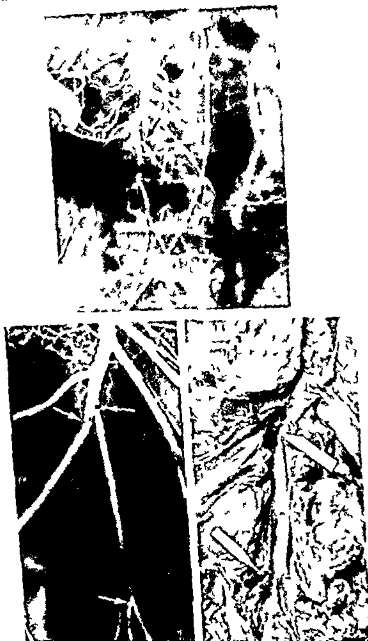


Fig 4 Selective superior mesenteric angiography in a female aged 77 five days after onset of symptom (upper view) Constriction of superior mesenteric arterial tree emboli hardly discernible (arrows) Post mortem injection study (lower left) Partially obstructing emboli in superior mesenteric artery and one intestinal artery (arrows) Dissected

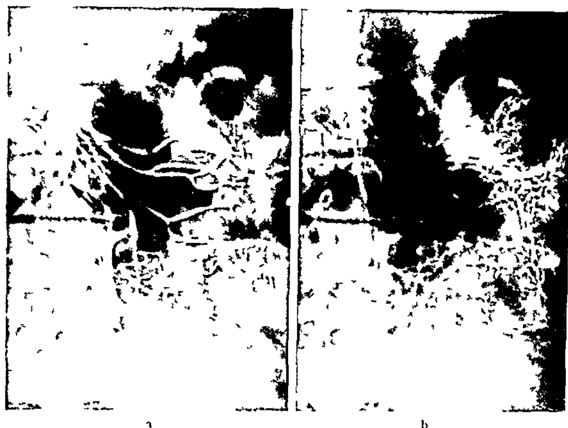


Fig. 3. a) Selective superior mesenteric angiography in a male aged 68 two days after onset of symptoms. Occlusion of superior mesenteric artery (arrow) with spastic contractions in branches proximally; *poor filling of the finer branches. b) After injection of dilating agent into superior mesenteric artery.* Spasms relieved, increased number and caliber of finer branches, marked dilution of medium due to increased blood flow.

Complete occlusion of the superior mesenteric artery was demonstrated in two patients. In one of these, arteriotomy had been performed on a clinical suggestion of 'mesenteric thrombosis' on the day before angiography. Complete occlusion of the superior mesenteric artery immediately distal to the ileocolic artery, and a marked narrowing of the branches arising proximal to the occlusion, were clearly shown (Fig. 2). The patient died 15 hours later, and the post mortem examination revealed thrombosis of the superior mesenteric artery corresponding to the angiographic finding. However, in spite of patent branches proximal to the occlusion the entire small bowel distal to the duodenum was gangrenous.

In one patient (Fig. 3a), angiography disclosed complete occlusion of the main stem just distal to the right colic artery with spastic contractions in the branches arising proximal to the occlusion. Following injection of a dilating



Fig 6 Selective superior mesenteric angiography in a female aged 58 16 hours after onset of symptoms Segmental constrictions in superior mesenteric artery and in one intestinal artery (arrows) Extensive constriction of the other branches (The patient died 10 hours later Autopsy revealed patent vessels and gangrene of the bowel from the duodenojejunal junction to middle of the transverse colon)

dissection of the arteries (Fig 4c) Patchy necrosis was found in the entire small bowel distal to the duodenum

In the remaining four patients no arterial occlusion was evident at angiography Marked arterial narrowing was however present in all four and associated in three of the patients with a distinctly reduced blood flow in the superior mesenteric artery (Fig 5a) The appearances of the arterial constrictions varied Generalized narrowing of the entire superior mesenteric arterial tree was present in some patients but the narrowing was particularly marked in the intestinal and colic branches (Fig 5b) Short segmental constrictions were evident in one patient (Fig 6) Markedly reduced filling of the finer arterial branches was a constant finding Three of the four patients were operated upon and marked cyanosis and patchy gangrene of the entire small bowel were found Pulsations were present in the superior mesenteric artery but disappeared at a varying distance from the bowel margin All these three patients died 6 to 18 hours after the operation Extensive necrosis of the small bowel in two patients of the right half of the colon as well was present at

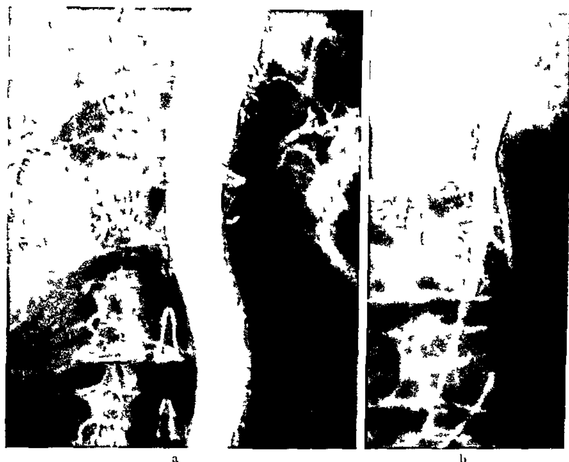


Fig 5 a) Aortography in a female aged 71 four days after onset of symptoms Delayed filling of superior mesenteric artery b) Selective superior mesenteric angiography manual injection to prevent aortic reflux Marked constriction of the superior mesenteric arterial bed (The patient died 12 hours later Autopsy revealed patent vessels and gangrene of the entire small bowel and right half of the colon)

agent, 0 04 g Tolazolin (2 benzyl 2 imidazoline hydrochloride), via the catheter into the superior mesenteric artery, these branches assumed an increased and regular caliber (Fig 3b) At operation two hours later necrotic bowel was found exactly corresponding to the ischemic area revealed by angiography The patient survived after resection of a necrotic ileal segment approximately 0 5 m in length

In another patient partially obstructing emboli were present in the superior mesenteric artery and in one intestinal artery Angiography revealed marked but varying arterial narrowing encompassing the entire superior mesenteric arterial tree The emboli could hardly be discerned (Fig 4a) The patient died 16 hours after the examination and the emboli were clearly demonstrated by the post mortem injection study (Fig 4b) as well as by the subsequent

necrosis of the intestinal tract associated with myocardial infarction These authors also described abdominal pain and distension associated with attacks of cardiac arrhythmia and presented experimental evidence suggesting marked mesenteric arterial constriction in shock states induced by trauma hemorrhage and cardiac arrhythmias

Splanchnic vasoconstriction in conditions with a reduced cardiac output would act to preserve the circulating blood volume for the more vital organs such as heart and brain Such a mechanism may be particularly critical if the bowel circulation already is marginal due to atherosclerosis of the splanchnic arteries Furthermore the intestinal smooth muscle will respond to ischemia with spasm and this spasm will add a further impediment to the microcirculation of the bowel by compressing the small vessels in the intestinal wall

Marked mesenteric vasoconstriction and intestinal necrosis have been demonstrated experimentally in shock due to hemorrhage, endotoxin epinephrine and temporary superior mesenteric artery clamping (LILLEHEI 1957 LONGERBEAM et coll 1962) *The conception of vasoconstriction as a cause of intestinal* gangrene encountered clinically is supported by the present demonstration of arterial narrowing in cases of bowel gangrene This vasoconstriction is thought to occur in the small straight and intramural vessels (JACKSON 1963) It is interesting to note from the present examinations that vasoconstriction takes place in the larger arteries as well A wide scale of constrictions and corresponding circulatory impairments probably exist and extensive experience with the angiographic method is needed to estimate correctly the nutritional state of the bowel in each instance

Gastrointestinal necrosis has also been attributed to drugs mainly pressor substances (BROWN et coll 1959) but including morphia (KATZ 1959) and digitalis (GAZES et coll 1961) Some of these drugs were used in the present material and intoxication by digitalis was considered probable in one patient No definite cause of the intestinal necrosis can thus be determined in each patient of the present series Our experience with visceral angiography hardly indicates that arterial constrictions of circulatory significance are produced by the procedure

Regardless of the precipitating factor the arterial constrictions in the present material were mainly localized to the superior mesenteric vascular bed Judging from the aortograms no major narrowing was present in the other aortic branches

Another interesting utilization of the selective catheterization is the treatment of vasoconstriction by local injection of a spasmolytic agent Vasoconstriction of the mesenteric vessels has been relieved clinically by splanchnic block (COTTALORDA 1946 ORR JR et coll 1954, SHAW 1959, HOFFMAN et

autopsy The patient who was not submitted to operation died 24 hours after angiography and a short necrotic segment of the ileum was evident post mortem None of the four patients had stenoses or occlusions of the vessels that could be detected macroscopically None of them had recent or old infarctions in organs outside the gastro intestinal tract, and only one had thrombi in the chambers of the heart Microscopy of the necrotic bowel wall and mesentery performed in only two of these four patients revealed no occlusions of the small vessels

Discussion

Occlusion of the superior mesenteric artery by thrombosis or embolism accounts for most cases of intestinal infarction The present material suggests that complete occlusion of the superior mesenteric artery is readily shown by angiography (Figs 2 and 3a), while the direct angiographic demonstration of an embolus not producing complete occlusion may offer considerable problems (Fig 4a) Marked and easily demonstrable arterial narrowing seems however to occur in both conditions as an accompanying phenomenon Furthermore, angiography, by the demonstration of the arterial constrictions explains the frequent discrepancy between the level of the arterial occlusion and the extent of bowel gangrene

Coexisting arterial spasm is generally said to occur in embolism to the extremities It is not surprising that concomitant arterial spasm also occurs in cases of thromboembolic occlusion of the superior mesenteric artery Such vasospasm is thought to be due to a reflex mechanism or release of vasoconstrictor substances (like serotonin) from the clot (GLOTZER & SHAW 1959) Vasoconstriction can probably also be ascribed occasionally to increased sympathetic tone produced by shock

The authors as yet have no experience with angiography in gangrene due to venous thrombosis or known disease of the small vessels of the bowel

Intestinal infarction in which no vascular occlusion can be detected at autopsy occurs with a varying frequency (up to 29 per cent) in different materials (JENSON & SMITH 1956 GLOTZER & SHAW, BERGER & BYRNE 1961 SOLHEIM 1963) The absence of emboli or thrombi may probably be ascribed sometimes to faulty autopsy technique, or fragmentation and fibrinolysis although a vasospastic mechanism is suggested by several authors (GLOTZER & SHAW, MING & LEVITAN 1960 BERGER & BYRNE, CORDAY et coll 1962) Clinical reports of intestinal necrosis associated with congestive heart failure were published by ENDE (1958) MING & LEVITAN found hemorrhagic necrosis of the gastrointestinal tract in patients with irreversible shock states congestive heart failure and cardiac arrhythmias CORDAY et coll reported hemorrhagic

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coll 1960). LIANG et coll (1961), in dogs with experimental ligature of the superior mesenteric artery, significantly improved the prognosis by continuous epidural anesthesia. Denervation of the abdominal viscera also increased the survival rate in animals with experimental hemorrhagic and endotoxic shock (PALMERIO et coll 1963). The relief of vasoconstriction by selective injection of a spasmolytic agent into the superior mesenteric artery forms a new aspect of treatment. In this respect the distinct effect of injecting Tolazolin in one of the patients of the present material is encouraging. HARDAWAY et coll (1961) suggested that vasospasm may augment capillary thrombi and vice versa in a vicious circle. This implies that fibrinolysis by means of fibrinolysin, injected via the catheter, also deserves serious consideration although the value of fibrinolytic therapy is at present incompletely understood (COHEN & WARREN 1961). It is recognised that the restoration of the blood flow in an ischemic bowel may result in shock (LILLEHEI 1957, MAVOR et coll 1962, BERGAN et coll 1964) but whether this represents a major objection to such therapy remains to be settled.

Acknowledgement

We are grateful to Dr E. Sivertssen, Medical Department VIII, Ullevål Hospital, for reviewing the ECG records.

SUMMARY

The angiographic findings in seven patients with acute superior mesenteric insufficiency resulting in bowel necrosis are presented. Complete occlusion of the main stem was readily demonstrated in two of the patients but direct signs of partially obstructing emboli were doubtful in one patient. In all these as well as in four patients without organic vascular occlusion marked arterial constriction was disclosed by angiography.

ZUSAMMENFASSUNG

Die angiographischen Befunde in sieben Patienten werden beschrieben, die an akuter Insuffizienz der Art. mesenterica superior mit Darmnekrose litten. Zwei Fälle zeigten kompletten Verschluss des Hauptstammes, in einem Falle war es zweifelhaft, ob Embolien mit unvollständigem Verschluss vorhanden war. In allen diesen und in vier Fällen ohne organischen Verschluss zeigte die Angiographie eine Verengung der Arterien.

RÉSUMÉ

Description des signes angiographiques chez sept malades atteints d'insuffisance aiguë de la mésentérique supérieure causant une nécrose intestinale. On a constaté une obstruction complète du tronc principal chez deux malades et des signes douteux directs d'obstruction partielle par emboles chez un malade. Chez tous ces malades ainsi que chez quatre malades qui ne présentaient pas d'obstruction vasculaire organique l'angiographie a montré une constriction artérielle marquée.

FROM THE DEPARTMENT OF THORACIC RADIOLOGY (DIRECTOR BJÖRN NORDENSTRÖM) KAROLINSKA SJUKHUSET STOCKHOLM SWEDEN

SELECTIVE CATHETERIZATION AND ANGIOGRAPHY OF BRONCHIAL AND MEDIASTINAL ARTERIES IN MAN

by

BJÖRN NORDENSTRÖM

Most of the vascular regions in man can now be catheterized or at least be examined roentgenologically with contrast injection in the vicinity of the trunks of the supply vessels Both in man and animals however, the bronchial and mediastinal vessels are probably to be regarded as among those most difficult of access Even in experimental examinations in animals this has to a great extent restricted the possibility of obtaining a clear conception of the normal function of this vascular system and of its significance in pathologic conditions The author has previously given a survey of the more important works in this field and attention will now be drawn only to the fact that the bronchomediastinal vessels constitute an anatomically independent system Moreover in a wide sense the bronchial arteries are of importance not only for the nutrition of the bronchi but also of the vessel walls lung parenchyma interstitial tissue pleura and lymph glands

Apart from the purely nutritive functions of the bronchomediastinal arteries

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there are probably also other and highly differentiated functions for different parts of this vascular system. As is known, the bronchial arteries have connections with the pulmonary circulation via precapillary, capillary and post capillary anastomoses. Modified bronchial arteries, so called 'Sperr arteries' (according to VON HAYEK, and VERLOOP), in this anastomotic system are considered to have the capacity of opening and closing certain parts of the branches of the terminal bronchial arteries. It is also known that the oxygen content in the blood of the pulmonary arteries can affect the circulation in the lung (NISELL), and that the lung is an important blood depot, the filling degree of which can scarcely be regulated by extrapulmonary factors alone (VON EULER & LILJESTRAND). The shunting of different amounts of arterial blood through the precapillary, capillary or postcapillary bronchopulmonary vascular connections should therefore affect the amount of circulating blood *and the blood depot of the lung. Such circumstances in themselves make it* probable that the bronchial circulation may have an important regulatory function in the pulmonary circulation.

Pathologic conditions in the human lung, such as tuberculosis and bronchiectasis, conditioned by inflammation (WRIGHT, MATHES et coll., WOOD et coll., MARCHAND et coll.) give rise to enlargement of the bronchial arteries. Distended bronchial arteries may also exist in connection with certain tumours in the lung or the bronchi.

Fallot's tetrad is one of the most common conditions in which disturbances occur in the bronchial circulation (see e.g. CHRISTELLER). Even ordinary roentgenograms may reveal the distended shunt vessels from the systemic to the pulmonary circulation formed by the bronchial arteries. Why these distended bronchial arteries exist in cases of Fallot's tetrad but not in cases of valvular pulmonary stenosis is not yet known, for in both conditions there is a corresponding fall in pressure from the systemic to the pulmonary circulation. It is possible that the bronchial arteries are not involved in the congenital *malformation, whereas this is probably the rule in valvular pulmonary* stenosis.

The nutritive vessels from the mediastinal arteries to the oesophagus, thymus, pericardium and mediastinal lymph glands might well be used in connection with preoperative investigation of these organs. Future possibilities of cytostatic treatment of mediastinal lymph nodes with a high local concentration of the drug should make perfusion via the bronchomediastinal arteries a most effective procedure.

Sufficiently strong reasons therefore existed for an attempt to reach the bronchomediastinal vascular system in man by means of selective catheterization. That the bronchial arteries in man as *well* as in *the dog* are accessible

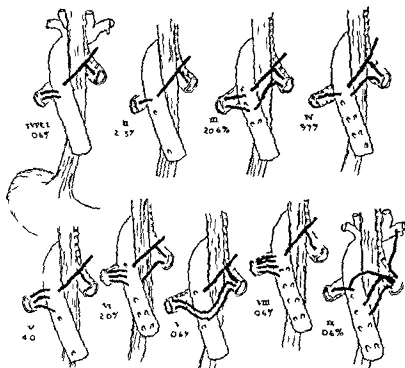


Fig 1 Types of origin of bronchial arteries compiled from CAULDWELL et coll (1949) Courtesy by the authors

for selective catheterization has been demonstrated in preliminary *reports* by the author and further experiences of selective bronchial arterial catheterization in the former are now presented All the attempts to date have been made only in patients suffering from inoperable lung carcinoma

A few reminders of the anatomy of the bronchomediastinal vascular system will first be necessary The individual variations in the size number and position of the arteries and their communications are *considerable* The following brief survey has been compiled from some of the textbooks of human anatomy (RAUBER KOPSCH CUNNINGHAM) *and* special works in this field (CAULDWELL et coll CUDKOWICZ et coll GHOREYEB et coll MILLER)

The posterior bronchomediastinal arteries *are usually* two in number one leaving the anterior wall of the aorta at *the level of the fifth* thoracic vertebra while the other generally starts just below both run diagonally downwards and laterally to the *posterior aspect* of the left main bronchus

Usually only one bronchomediastinal artery arises on the right side of the

first branch of the first, second or third intercostal artery, or from the uppermost left bronchial artery. It may also arise direct from the aorta.

The bronchomediastinal arteries sometimes take their origin from the lower anterior wall of the arch of the aorta, from the subclavian artery, internal mammary or arteria thyreoidea caudalis. Smaller branches arising from the arch are generally regarded as accessory bronchial arteries and called rami bronchiales.

The posterior bronchomediastinal arteries anastomose in the mediastinum with the weakly developed anterior bronchomediastinal arteries, from the internal mammary artery, or from the anterior parts of the intercostal arteries.

The pericardiacophrenic artery, which constitutes the largest branch from the internal mammary artery, ramifies in the pericardium, mediastinum and pleura with branches from the posterior bronchomediastinal arteries; anastomoses with branches from the epigastric and inferior phrenic arteries also occur. The types of bronchial arterial supply were carefully studied by CAULDWELL et coll. in 150 cadavers, their classification, based upon the origin, number and course of the vessels, is illustrated schematically in Fig. 1.

Technique of preliminary investigation

Owing to the great individual variations in the origins of the bronchomediastinal arteries, it is as yet too hazardous to attempt direct catheterization of these without a special preliminary investigation. Aortography is therefore performed to chart the reciprocal positions of the arterial branches arising from the thoracic aorta. It may take three forms, as follows:

1. *Ordinary thoracic aortography.* The contrast filling of intercostal and bronchial arterial branches not markedly distended is often rather poor. The origin of the bronchomediastinal arteries may not be determined.

2. *Thoracic aortography with temporary external compression of the abdominal aorta.* The intention is to check the aortic flow in order to fill the small arterial branches more readily. The bronchial arteries, if sufficiently wide, may sometimes be well outlined.

3. *Temporary occlusion of the middle part of the thoracic aorta with a balloon catheter with injection at the origin of the left subclavian artery.* This last method is definitely the most effective of the three and, with its risks and possibilities, has been discussed earlier (NORDENSTROM 1954, NORDENSTROM & TORNELL 1966). A further measure designed to increase effectiveness in aortography with temporary closure of the aorta consists in the application of a cuff to the left upper arm to reduce contrast losses via the brachial artery.



F g 2 Thora ic aortography in a 67 year-ol l man w th left-sided oat c ll arc noma an l large lymph glands in the left h lum Upper t ew Irr gularl tap ng arteri l bra ch presumably due to tumour invasion in the vessel wall l es below the aortic arch Lower ti w Selective catheterizat on No med um d stal to the na rowing but some has p assed along the catheter to an i tercostal a tery located h gher up and across t e mediastinum to a right intercostal artery

Direct serial roentgenography will ensure satisfactory sharpness of detail either stereoscopic or intermittent exposure in two projections at right angles should be used The dose employed 1 ml/kg bodyweight Urografin 60 % will necessitate that only one injection be made during temporary occlusion of the aorta

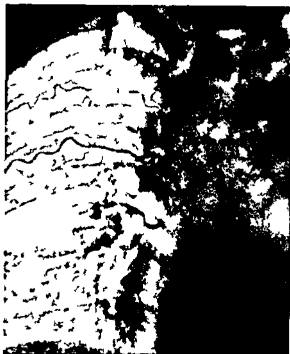


Fig. 3. From same patient as in fig. 2, attempt at catheterization of the right bronchial artery. *Contrast injection into an intercostal artery filled* one intercostal artery located above and one below as well as vascular branches in the mediastinum.



Fig. 4. From same patient as in figs. 2 and 3. The catheter is now placed in an arterial *branch located higher up than in fig. 3. The test* injection of a small amount of medium filled the bronchial artery of the right lower lobe. The patient had been turned somewhat to the right.

Selective catheterization

The potential risks that may eventually be entailed must be considered for each new vascular region to be catheterized and injected selectively.

It should be borne in mind that as a rule small arterial branches to the spinal cord, the rami spinales, arise from the first parts of both the intercostal and bronchomediastinal arteries. Selective catheterization of intercostal or bronchomediastinal arteries is at present scarcely possible without test injections *of contrast medium for the determination of the position of the point of the* catheter. On account of the risk of damaging the spinal cord, the test injections must therefore be made with caution. If it is possible to push the catheter relatively far out in an intercostal or bronchomediastinal artery and past the *point of origin of a ramus spinalis,* the risks for the spinal cord are of course no longer present.

The catheterizations have been performed under fluoroscopy with image intensifier and television equipment after a preliminary charting of the arterial branches arising from the thoracic aorta, as a rule the day before



Fig 5 From same patient as in figs 2 3 and 4 Contrast injection into the right bronchial artery which is probably normal Small arterial branches in the mediastinum and left intercostal arteries have also been filled

An account of the instruments used was given by the author (1963) in a report on the first selective catheterization of bronchial arteries in man

A roentgen opaque polythene catheter the point of which had been drawn out to a length of about 4 cm is dimensioned externally and formed in accordance with the information gained from the preliminary examination so that it may be introduced in the easiest way into the bronchial artery It is passed percutaneously under local anesthesia into the femoral artery Differently curved or straight mandrins of silver steel are used for the purpose of slightly varying the curve of the catheter point and are either rather stout with a rounded point or are provided with a protective knob These mandrins must never project beyond the point of the catheter as a hard mandrin may easily cut the intima or perforate the vessel wall A curved rigid mandrin will enable accu



Fig 6 Selective catheterization with contrast injection into the probably normal right bronchial artery The medium passed also to a right intercostal artery and to small mediastinal arteries and rami tracheales

rate movements of the point of the catheter to be made A further improvement is effected if the part of the mandrin outside the catheter is bent to an angle of 90 ° so that it forms an indicator of the direction of the catheter point in the aorta A three way stop cock of a type earlier described makes it possible to inject small amounts of contrast medium into the catheter while the mandrin is retained in situ

Cautious exploratory movements are made with the point of the catheter in the longitudinal direction of the aorta and by turning the mandrin under fluoroscopic control, at the calculated site of origin of the bronchial artery The tip of the catheter will occasionally get caught in a vessel whereupon a few milliliters Urografin 40 % are injected, it is usually found that an intercostal artery has been injected The position of this artery in relation to easily observable surrounding structures and to the vessel sought is then determined and the work concentrated to a smaller area When the catheter has been

introduced into the correct vessel the mandrin must sometimes be withdrawn so as to allow the soft point of the catheter to follow the direction of the vessel This must be performed very carefully, as a slight twist of the mandrin may suffice to draw the catheter out of the vessel

For angiography of the bronchial arteries manual injection of about 15 to 20 ml Urografin 60 % is made immediately followed by the roentgen exposures No more than two injections should be given at each investigation, in order to avoid unnecessary risks of damage by the contrast medium until more experience has been gained

Results

Catheterization with current selective bronchial angiography has so far been tried out in 10 patients in two of whom it failed

A slight positive Babinski reaction was present for 24 hours in connection with one angiographic examination The cause appeared to be clear Three injections each of about 15 ml Urografin 76 % instead of Urografin 60 % had been given The signs disappeared spontaneously A hematoma occurred in the groin of one patient at the site where the catheter was introduced About 2 weeks after the catheterization a secondary infection developed and removal of the hematoma was planned Before this could be carried out however the patient died of the primary condition a large, inoperable bronchial cancer eroding the thoracic wall There were no other complications in connection with either the preliminary aortographies or the selective catheterizations and injections

The contrast injections into the bronchial or intercostal arteries were without exception accompanied by considerable pain and particularly by an intense burning sensation in the thorax contrast injection during nitrous oxide anes thesia produced no pain No reactions from the pulmonary vascular system or the bronchi e g in the form of coughing dyspnea increased secretion or asthmatic attacks were observed

Films from a bronchial arterial catheterization of a 69 year old man with an oat cell carcinoma of the left lung are reproduced in Figs 2 to 5 A walnut sized tumour in the lingula was accompanied by large lymph glands in the left hilar region In Fig 2a ordinary thoracic aortography without occlusion of the aorta with a balloon catheter or compression of the abdominal aorta is depicted Even in the preliminary films it was possible to observe a somewhat irregularly narrowed artery running to the left hilum At selective catheteriza tion and contrast injection the artery was found to be occluded but a certain amount of contrast medium passed along the side of the catheter to an inter costal artery situated above it and moreover across the mediastinum to



Fig. 6. Selective catheterization with contrast injection into the probably normal right bronchial artery. The medium passed also to a right intercostal artery and to small mediastinal arteries and rami tracheales.

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SUMMARY

A technique for the selective catheterization and injection of the bronchomediastinal arteries in man is described and illustrated. All the risks that may conceivably arise in these investigations are discussed. The technique should afford possibilities not only of morphologic examinations in vivo but of examinations of the function of this in many respects unexplored vascular system.

ZUSAMMENFASSUNG

Eine Technik fur die selektive Einfuhrung eines Katheters und fur die Kontrastfullung der bronchio-mediastinalen Arterien in Menschen wird beschrieben und illustriert. Alle Risikos die bei dieser Untersuchung moglicherweise entstehen konnen werden besprochen. Das Vorgehen sollte nicht nur morphologische Untersuchungen an Lebenden sondern auch funktionelle Erscheinungen in die ein wenig bekannten Gefassbereich ermoglichen.

RÉSUMÉ

L'auteur décrit une technique de cathétérisme électif et d'injection des artères broncho-médiastinales chez l'homme et en donne des exemples. Il examine tous dangers imaginables de ces examens. Cette technique devrait offrir la possibilité d'étudier in vivo non seulement la morphologie mais aussi les fonction de ce système vasculaire qui est à bien des égards inexploré.

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an intercostal artery on the right side It was assumed that the bronchial artery was possibly compressed by the hilum or narrowed by malignant tissue The investigation was then continued with an attempt to catheterize what was presumed to be the normal right bronchial artery The catheter passed first into two intercostal arteries, and the injection of medium into the one of these outlined three intercostal arteries (Fig 3), some of the medium also passed into small mediastinal arteries A test injection after the catheter had been introduced into an arterial branch arising higher up the aorta revealed some bronchial arteries to the right lower lobe (Fig 4) On the injection of about 20 ml Urografin 60 %, with the patient supine, further branches to the right bronchial artery, some small mediastinal arterial branches, and intercostal arteries to the left lung were also outlined (Fig 5)

The left bronchial artery could not be catheterized in a patient with a left sided bronchial carcinoma with advanced changes in the left hilar region Attempts were then made to catheterize the right bronchial artery (Fig 6) Contrast filling of small mediastinal and tracheal branches, as well as of intercostal arteries on the left side, was attained

Discussion

The significance of the bronchomediastinal vascular system has to a large extent not yet been elucidated There is much to support the assumption that it possesses not only a nutritive function for the mediastinum bronchi, lung vessels, lung parenchyma and pleura but may also be of importance in pathologic conditions and for regulation of the pulmonary circulation Relatively little is known about these vessels, probably because of their difficulty of access Selective catheterization and angiography of the bronchomediastinal arteries are, however, possible to perform With increasing experience, it is reasonable to assume that the technique may be considerably simplified In attempts at selective catheterization of the bronchial arteries in man it is of the greatest importance that in the preliminary investigation — or at all events if the aorta is temporarily occluded — only one contrast injection should be given Furthermore, only media of a concentration and volume that have previously been found to be without risk in experiments in animals should be employed Great care must be exercised with respect to the rami spinales of the spinal cord when undertaking selective catheterization with injections into the bronchial artery or intercostal arteries The examination must be carefully planned in all details in order to reduce the number of test injections for the control of the position of the catheter Only small amounts of Urografin 10 % are generally required to check the position of the catheter in an intercostal or bronchial artery

SUMMARY

A technique for the selective catheterization and injection of the bronchomediastinal arteries in man is described and illustrated All the risks that may conceivably arise in these investigations are discussed The technique should afford possibilities not only of morphologic examinations in vivo but of examinations of the function of this in many respects un explored vascular system

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RESUME

L auteur décrit une technique de cathétérisme électif et d injection des arteres broncho-mediastinales chez l homme et en donne des exemples Il examine tous dangers imaginables de ces examens Cette technique devrait offrir la possibilité d étudier in vivo non seulement la morphologie mais aussi les fonction de ce systeme vasculaire qui est a bien des égards inexplore

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Fig 1 The usual appearances of the middle lobe bronchus in a true lateral tomogram





b

Fig 2 a True lateral tomogram b Special projection The middle lobe bronchus is better shown in this projection

these bronchi directed parallel to the film plane are employed Certain bronchi especially those of the middle and lingular lobes are well adapted to such a technique

The author has found however that this technique is seldom used The middle lobe bronchi as well as the lingular bronchi are usually evaluated in the true lateral tomogram this projection seems to be preferred even if the investigation directly concerns the middle and lingular lobes (SCHULZE 1962 TRENDELENBURG & VIRCHOW 1962) As changes often occur in the middle and lingular lobe bronchi there are adequate reasons for a closer study of the possibilities of a more thorough tomographic analysis

FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR PROF F KNUTSSON), THE UNIVERSITY HOSPITAL, UPSALA, SWEDEN

TOMOGRAPHY OF THE MIDDLE AND LINGULAR BRONCHI

by

HERMAN LODIN

Both bronchography and tomography are used in the examination of the bronchi, the former usually giving more information than the latter Tomography is more commonly accepted for the trachea and the main bronchi while bronchography is mostly used for other parts of the bronchial tree Tomography causes neither subjective nor objective respiratory difficulties while bronchography may be contra indicated for these reasons, especially in older subjects

Tomography should be used to gather as much information as possible of changes in the parenchyma, as well as in the bronchi, when bronchography appears to be unsuitable

As the main purpose of tomography is the investigation of parenchymatous changes, true frontal and lateral projections are used, information is thus obtained about the bronchi that lie roughly parallel to these two planes The bronchi forming an angle with the tomographic plane are only incompletely projected and cannot be properly examined unless special projections, with

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Fig 4 a) True lateral tomogram b) Special projection in which the lingular bronchus is better shown (→)

branches even if they are unfavourable situated as far as the tomographic plane is concerned This applies also to the lingular bronchus

In order to study the tomographic reproducibility of the middle lobe and lingular bronchi when conventional projections are used i e true lateral projection with 1 cm between the tomographic layers, an analysis has been made of 100 right and 50 left lung tomograms The lungs in this material showed no changes that could affect the position and shape of the middle or lingular lobes and the parenchyma of these two lobes in no instance displayed any abnormality There was no enlargement of the hilar glands

Results

The middle lobe bronchus was outlined in the 100 lateral tomograms investigated In 7 cases it was impossible to delineate the bronchus probably because it was directed markedly laterally In 31 cases it was possible to see 1 cm of its length in 33 cases 1 5 cm (Fig 1) in 15 cases 2 cm, in 8 cases 2 5 cm and in 6 cases 3 cm It was also possible to observe the first part of the two segmental bronchi in 11 cases four of those are included in the group in which the bronchi lay within an area of 1 5 cm measured from the stem bronchus An early division of the lobar bronchus into segmental bronchi must evidently have taken place in these cases The middle lobe bronchus has usually terminated typically as a bronchus leaving a tomographic layer and there has been no tomographic characteristics of bronchial stenosis In some cases however the bronchial termination could be interpreted as a stenosis but examination in a projection more suited to the anatomy of the bronchus disclosed no change

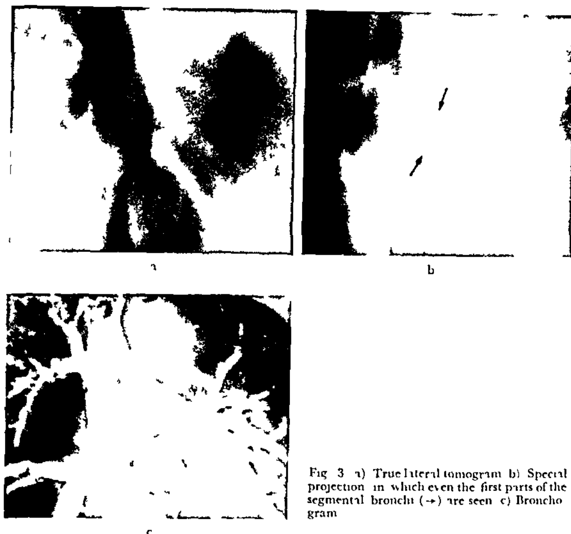


Fig. 3. a) True lateral tomogram. b) Special projection in which even the first parts of the segmental bronchi (→) are seen. c) Bronchogram.

The middle lobe bronchus, the length of which is stated to be 12 to 26 mm (TRENDELENBURG & VIRCHOW 1962) forms inconstant angles with both the frontal and sagittal planes of the body, being directed at the same time frontally and laterally. The factors influencing these angles are, among other things, the thoracic shape, the amount of air inspired, and changes within the middle lobe or other parts of the lung affecting the site of the middle lobe through variation in volume and scarring processes. The amount of air in the adjacent tissues is of great importance, as the tomographic reproduction of the middle lobe bronchus as well as that of other bronchi is dependent merely on the contrast between their contents and the surrounding areas. Infiltration of the lung parenchyma within the middle lobe, and the presence of enlarged hilar glands, improve the reproduction of the air filled bronchus and its



Fig 6 a) True lateral tomogram Middle lobe bronchus not visible b) Special projection Total stenosis (→) verified at operation (Malignant tumour)

and the adjacent air filled parenchyma is very much reduced by the proximity of the ray absorbing heart

In an earlier article the author has recommended a special projection for investigation of the middle lobe bronchus and the lingular bronchi When the patient is turned backwards 10 to 20° from the true lateral position the direction of these bronchi to the tomographic plane becomes more favourable This oblique projection has been employed in our department since 1953 as a routine method in middle lobe investigations and has proved most satisfactory An improvement in the tomographic detail has been achieved in almost every case where no change in the position of the middle lobe existed (Figs 2 and 3) This is natural as the middle lobe bronchus always runs a more or less lateral course The improved tomographic result is obviously most marked where the true lateral tomogram can include only a short part of the bronchus The accuracy in diagnosis of stenosis is increased and, in cases of parenchymal infiltration the bronchi if air filled can often be observed in the same tomogram This is also true although to a lesser degree of the bronchi within the lingular lobe (Fig 4) A greater improvement in the reproduction is prevented by the proximity and movements of the heart

The special projection is seldom superior to the true lateral projection in cases in which changes mainly within the other parts of the lung alter the position of the middle lobe

The tomographic technique is further illustrated by a comparison between the true lateral tomogram and tomograms obtained in the recommended

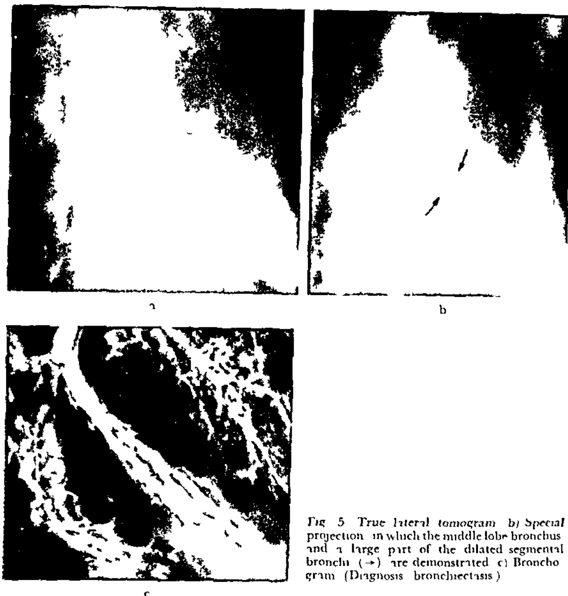


Fig 5 True lateral tomogram b) Special projection in which the middle lobe bronchus and a large part of the dilated segmental bronchi (→) are demonstrated c) Bronchogram (Diagnosis bronchiectasis)

The appearance of the bronchial termination in these cases has been explained as an early division into segmental bronchi, it has been possible to define clearly this division in the special projection

The lingular bronchus was examined in 50 lateral tomograms but only in a few of these was it possible to delineate its first part Special conditions exist in the left lung, especially in the lingular bronchus, and have been discussed previously (Lodin 1953) This bronchus is situated close to the heart and follows the pulsations so that the sharpness of the tomogram is lessened at the exposure times needed Furthermore the contrast between the lingular bronchus wall



Fig 6 a) True lateral tomogram Middle lobe bronchus not visible b) Special projection Total stenosis (→) verified at operation (Malignant tumour)

and the adjacent air filled parenchyma is very much reduced by the proximity of the ray absorbing heart

In an earlier article the author has recommended a special projection for investigation of the middle lobe bronchus and the lingular bronchi When the patient is turned backwards 10 to 20 from the true lateral position the direction of these bronchi to the tomographic plane becomes more favourable *This* oblique projection has been employed in our department since 1953 as a routine method in middle lobe investigations and has proved most satisfactory An improvement in the tomographic detail has been achieved in *almost* every case where no change in the position of the middle lobe existed (Figs 2 and 3) This is natural as the middle lobe bronchus always runs a more or less *lateral course* The improved tomographic result is obviously most marked where the true lateral tomogram can include only a *short* part of the bronchus The accuracy in diagnosis of stenosis is increased and in cases of parenchymal infiltration the bronchi if air filled can often be observed in the same tomogram This is also true although to a lesser *degree, of the* bronchi within the lingular lobe (Fig 4) A greater improvement in the reproduction is prevented by the proximity and movements of the heart

The special projection is seldom superior to the true lateral projection in cases in which changes mainly *within* the other parts of the lung alter the position of the middle lobe

The tomographic technique is further illustrated by a comparison between the true lateral tomogram and *tomograms* obtained in the recommended

oblique projection in two cases with pathologic changes in the middle lobe *bronchus and its branches (Figs 5 and 6)* *The value of using a special projection* in examining the bronchus is evident

Conclusions

The true lateral tomogram usually enables a good demonstration of the middle lobe bronchus to be made, including its first part, but may give a false impression of stenosis The information obtained from the lateral tomogram about the lingular bronchus is often indefinite A special procedure is recommended to obtain the best possible information about the middle lobe and its bronchi The true lateral tomogram should be complemented with a tomogram in an oblique projection, with the patient turned backwards 10 to 20° from the lateral decubitus position The distance between the tomographic layers in this special projection should be 0 5 cm, which gives a better chance of discerning any possible stenosis The tomographic evaluation of the lingular bronchus and lingular segments is however seldom improved with this special projection as compared with the true lateral view

SUMMARY

The tomographic appearances of the middle lobe bronchus and the lingular bronchus in true lateral projections are discussed It is possible to obtain more accurate information on the middle lobe bronchus and its branches with a special projection but a special view seldom appears to improve the evaluation of the lingular bronchus

ZUSAMMENFASSUNG

Das tomographische Bild des Mittellappenbronchus und des lingulären Bronchus im Seitenbild wird beschrieben Es ist möglich bessere Bilder des Mittellappenbronchus und ihrer Äste durch Spezialeinstellungen zu erhalten aber dies gelingt selten für den lingulären Bronchus

RÉSUMÉ

L'auteur décrit l'image tomographique de la bronche du lobe moyen et de la bronche de la lingula en incidence de profil franc Il est possible d'obtenir des données plus exactes sur la bronche du lobe moyen et ses branches par une projection spéciale cependant il semble qu'une incidence spéciale n'améliore que rarement l'examen de la bronche de la lingula

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FROM THE ROENTGEN DEPARTMENT (DIRECTORS O PETERSEN M EIKEN AND S BRUNNER) AND THE OTOLOGIC DEPARTMENT (DIRECTOR N RISKAER) COPENHAGEN COUNTY HOSPITAL GENTOFTE DENMARK

THIN SECTION TOMOGRAPHY IN DIAGNOSIS OF CHOLESTEATOMA OF TEMPORAL BONE IN CHILDREN

by

A BERRETT S BRUNNER L E SANDBERG and O PETERSEN

The diagnosis of cholesteatoma can often be made by clinical examination but roentgen examination is frequently of value In a large series of cases, mainly adults a diagnosis of cholesteatoma was made from conventional roentgenograms in about 60 to 70 % of cases (JENSEN et coll 1960, CHIAT & KITTREDGE 1958) By employing in addition thin section tomography (polytome) it is possible to make a positive diagnosis in a much higher percentage of cases Radiographic examinations are particularly helpful when for anatomical reasons or because of a clogged external auditory meatus it is difficult to inspect the drum Also a persistent or recurrent attic granuloma may obscure a cholesteatoma which lies behind it (MAWSON 1963)

Material Between 1957—1963 25 children with cholesteatomas have been operated upon at our hospital All cases were subjected to radiographic ex

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Table 1

Age and sex distribution in the total material of 25 cases

Age in years	Number of cases	Sex	
		M	F
0— 5	4	4	0
6—10	8	5	3
11—15	13	8	5
	Total	17	8

aminations, both conventional and with tomography (polytome) prior to surgery. There were 17 boys and 8 girls varying in age from 1 to 15 years (Table 1).

Clinical diagnosis (see Table 2). Clinical diagnoses were made by the Otologic Department in 12 of the cases. Chronic otitis media is nearly always present and it is often associated with a perforation of the ear drum. Also, definite cholesteatomatous crystals may be demonstrated following syringing. The remaining cases were diagnosed by a combination of clinical and radiological methods.

An early diagnosis of cholesteatoma by means of a complete and thorough roentgen examination is of great importance for the following reasons: (1) symptoms may be severe, (2) with delay, serious complications may occur, leading to irreversible damage with loss of hearing, (3) the information obtained will aid the surgeon by providing an indication for operative intervention.

It is therefore obvious that a roentgen examination should be performed without delay so that an operation or other form of therapy can be undertaken before there is irreversible damage.

Table 2

Establishment of a pre-operative clinical diagnosis in the total material of 25 cases

	Number of cases
Definite cholesteatoma	12
Possible cholesteatoma	1
Osteomyelitis	12

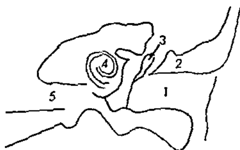


Fig 1 Schematic illustration of a p cut through cochlear plane (left side) 1 — external auditory meatus 2 — spur 3 — ossicles 4 — cochlea 5 — internal auditory meatus

Conventional radiography The following routine radiographic projections are employed in this department for the mastoid region Schuller s Stenver s, Towne s and transorbital

With such films only we were able to make a definite or a possible diagnosis of cholesteatoma in 5 out of the 25 cases The diagnosis of cholesteatoma only from conventional roentgenograms is frequently difficult The small ones are particularly hard to detect Satisfactory films in such projections as Schuller and Stenver are not easy to obtain in the pediatric age group In general with conventional radiography alone only information about pneumatization and inflammatory changes is obtained The small structures in the ear are however seldom demonstrated

Tomography

In the last few years prior to surgery, we have employed thin section tomography in the radiographic examination of all our cases of cholesteatoma of the temporal bone With this we have been able to demonstrate such structures as the ossicles labyrinth cochlea intra temporal part of the facial canal and the semicircular canals (BRUNNER et coll 1961 VALVASSORI 1963) Our routine in all cases is to obtain tomographic cuts in the a p projection (Fig 1) This is particularly valuable because of the possibility to compare the two sides on a single film Using hypocycloid movements we have been able to obtain cuts as thin as 1 mm The a p views are obtained with the patient lying supine, with the orbito meatal line perpendicular to the table top (BRUNNER et coll 1961)

The lateral views are obtained with the head in lateral position and the normal side down since lying on the affected ear may be painful

We have found this method of great value in the investigation of all our cases of cholesteatoma It has provided information about location size and exact extent of the cholesteatoma This type of detailed and complete examination

Table 3

Radiologic diagnostic results of tomography carried out in the total material of 25 cases

Age in years	Definite cholesteatoma	Possible cholesteatoma	No cholesteatoma
0—5	3	0	1
6—10	1	5	2
11—15	5	6	2
	Total 9	11	5

has allowed us to make a definite diagnosis, or suggest the possibility of cholesteatoma, in 80 % of this series of cases (Table 3).

It should be stressed that this is a complex, time consuming procedure which may require anesthesia. It is therefore of the utmost importance to select the cases carefully for this type of examination.

As one is working with cuts as thin as 1 mm in width, the patient must lie absolutely still during the procedure, and to achieve this the assistance of an anesthesiologist is essential (BRUNNER & BUCKMANN 1963).

The following routine is employed in this hospital.

1. For infants under one year of age a 'lytic' cocktail is used. This consists of a mixture containing per millilitre 28 mg pethidine or demerol (meperidine hydrochloride), 7 mg promethazine, 7 mg chlorpromazine. The dose employed is 0.05 ml per kg bodyweight. With this the infants usually sleep soundly throughout the tomographic procedure.

2. Between one and 6 or 7 years, pentothal sodium is administered rectally. The standard anesthetic machine is not considered suitable because of the

Table 4

Location and size of the cholesteatomas diagnosed by tomography in the total material of 25 cases

Location	Number of cases	Large	Medium	Small	No information
Antrum, Aditus, Attic	17	12	2	1	2
Attic only	6	1	0	2	3
Antrum only	2	1	1	0	0
Total	25	14	3	3	5

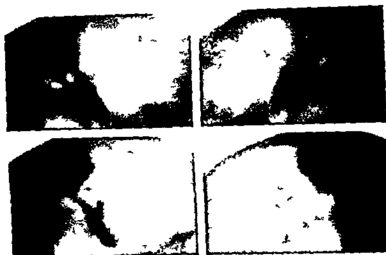


Fig. 2 Large cholesteatoma found at operation in the attic and antrum in a 3 year old boy with chronic infection in the left ear for one year. *Upper views* of cochlear plane: destruction of the spur and ossicles on left side; right side normal. *Lower views* of antrum plane (cut a few millimetres more posteriorly than in upper views): a large cholesteatoma cavity is seen in the region of the antrum.

various appliances generally encountered in the region of the head and neck. The children have nothing by mouth for 5 to 6 hours prior to the procedure. This is done in order to avoid aspiration of gastric contents. No premedication is needed. Pentothal sodium as a rectal suspension in a disposable plastic syringe with a detachable plastic rectal applicator is supplied ready for use and is very easy to administer.

As this may give rise to respiratory depression, apparatus for respiratory resuscitation must be within easy reach. The children should be under constant supervision for about an hour after the administration of the pentothal sodium.

3. Empirically, children over 6 or 7 years need no special sedation or medication for this examination.

Location and size of the cholesteatoma. We have adopted the classification of WINDEREN & ZIMMER (1954) to group our cases into large ("bean sized" and larger), small ("pea sized" and smaller) and medium (the size between these two extremes).

The majority of the cholesteatomas encountered in our series were large and tended to involve the antrum, aditus and attic. Relatively few were confined only to the attic or the antrum. The location and size of the cholesteatomas have been verified at operation (see Table 4).

Table 3

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Age in years	Definite cholesteatoma	Possible cholesteatoma	No cholesteatoma
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It should be stressed that this is a complex, time consuming procedure which may require anesthesia It is therefore of the utmost importance to select the cases carefully for this type of examination

As one is working with cuts as thin as 1 mm in width, the patient must be absolutely still during the procedure, and to achieve this the assistance of an anesthesiologist is essential (Brunner & Buckmann 1963)

The following routine is employed in this hospital

1 For infants under one year of age a 'lytic cocktail is used This consists of a mixture containing per millilitre 28 mg pethidine or demerol (meperidine hydrochloride), 7 mg promethazine, 7 mg chlorpromazine The dose employed is 0 05 ml per kg bodyweight With this the infants usually sleep soundly throughout the tomographic procedure

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Location and size of the cholesteatomas diagnosed by tomography in the total material of 25 cases

Location	Number of cases	Large	Medium	Small	No information
Antrum / Aditus / Attic	17	12	2	1	2
Attic only	6	1	0	2	3
Antrum only	2	1	1	0	0
Total	25	14	3	3	5

to see when there is extensive pneumatization of the temporal bone which rarely occurs however Speaking very generally, large cholesteatomas are relatively easy to demonstrate while small ones present considerable difficulty

It is important to differentiate a cholesteatoma cavity from a normal mastoid antrum MACMILLAN (1936) stated that the mastoid antrum measures 10 mm in vertical and 6 mm in its transverse diameters WALTNER (1949) stated that the vertical height could reach 11 mm He further postulated that the maximum width could exceed 6 mm without a cholesteatoma being present However the transverse diameter in the lower third of the antrum normally does not exceed 6 mm and the antrum is therefore cone shaped with the point towards the aditus in the a p projection With large cholesteatomas in the region of the antrum the outline of the antrum is frequently very distinct and thus its size becomes easy to measure Cholesteatomas which are confined to the antrum alone will produce no destruction of the spur By the term spur we mean the supramedial lip of the osseous external auditory canal and lateral wall of the attic

Cholesteatomas confined only to the attic are more difficult to diagnose because they do not produce a cavity but tend to result in destruction of the spur ossicles and in some cases of the cochlea and the semicircular canals Radiologically this may resemble chronic osteomyelitis (Fig 3)

An important point which is of considerable help in the differential diagnosis is to determine whether or not the spur is involved In a little more than 60 % of our cases of cholesteatoma the spur was found to be involved This is unusual to find in osteomyelitis per se

Conclusions

With our present methods and experience using both conventional roentgen examination and tomography (polytome) we are able to make a definite diagnosis or suspect a cholesteatoma in about 80 % of cases We are convinced that it is of great importance to perform tomography of the temporal bone in children who are suspected of having a cholesteatoma This we believe is an excellent method of demonstrating and diagnosing cholesteatomas pre operatively

SUMMARY

In the years 1957—1963 25 children with cholesteatomas have been operated upon at the Copenhagen County Hospital in Gentofte All the cases were roentgen examined employing both conventional radiography and tomography (polytome) prior to surgery Aided by thin section tomography we are able to make a definite diagnosis or suspect a cholesteatoma in about 80 of cases



Fig. 3. Large cholesteatoma found at operation in the attic and antrum of a 4-year-old girl with chronic inflammation in the left ear for 6 months. *Upper views* of cochlear plane: destruction of the spur and ossicles on left side, right side normal. *Lower views* of antrum plane: a large cholesteatoma cavity is seen in region of left antrum; right side normal.

Radiographic appearances

Usually a cholesteatoma presents as a more or less rounded area of erosion with a well defined *marginal sclerosis*. This sclerosis surrounds the area of erosion, giving it a dense border which is frequently round, even, and sharply defined (Figs. 2 and 3). Cholesteatomas usually occur in combination with chronic infection, resulting in a sclerotic cell system which allows easy demonstration of the cholesteatoma cavity. On the other hand, the cavity is difficult

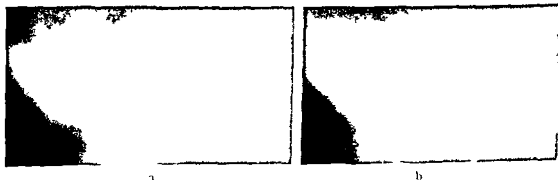


Fig. 4. Cholesteatoma found at operation in the attic of a 6-year-old boy with long-standing right-sided otitis. Tomography performed only on right side. a) Cochlear plane. Destruction of the spur and ossicles. b) Antrum plane normal.

FROM THE DEPARTMENT OF RADIOLOGY (DIRECTOR J D MUNN) THE HOSPITAL FOR SICK CHILDREN TORONTO CANADA

TRANSVERSE CLEFT IN THE BASI OCCIPUT

by

E KRUYFF

According to HERVE (1911) the first case of basi occipital cleft was reported by LALLEMAND in 1818 in an anencephalic Among others who reported this transverse cleft should be mentioned ST HILAIRE (1822) ALBRECHT (1884), SERGI, BARTELS (1904) and LEDOUBLE (1903) The part of the basi occiput distal to the cleft was named os basioticum by ALBRECHT and os praebasiocci pitale by SERGI LEDOUBLE collected nine cases from the literature and added one of his own all with complete separation of the os praebasioccipitale from the remaining basi occiput BARTELS reported this condition in a chinese skull in which transverse clefts were present bilaterally at the level of the tuber culum pharyngeum A midline sagittal section through the basi occiput at the level of the bridge showed a septum like structure consisting of thicker bone plates dividing the basi occiput into two

Several of the reported cases were monsters or abnormal fetuses HERVE s case was that of a newborn hydrocephalic in which a total cleft had occurred He claimed that the basioticum was separated from the basi post sphenoid the basi-occiput and the ossa petrosa by means of cartilage HERVE however did not mention if this cartilage indeed was observed in microscopical studies Most of the basi-occipital clefts were recorded in dry skulls The cleft and its

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ZUSAMMENFASSUNG

In den Jahren 1957—1963 wurden 25 Kinder mit Cholesteatom in dem Copenhagen County Hospital in Gentofte operiert. Alle waren vor der Operation röntgenologisch und tomographisch (polytome) untersucht worden. Mit Tomographie war es möglich in etwa 80% der Fälle eine definitive Diagnose festzustellen oder ein Cholesteatom zu verdächtigen.

RÉSUMÉ

De 1957 à 1963 25 enfants atteints de choléstéatome ont été opérés au Copenhagen County Hospital à Gentofte. Ils ont tous été examinés radiographiquement et tomographiquement (polytome) avant l'opération. Aidés par la tomographie en couche mince, nous étions en mesure de faire le diagnostic ferme ou de soupçonner un choléstéatome dans environ 80 % des cas.

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Fig Roentgenogram of sphenoid basi occiput and ant r or rim of foramen magnum basal view Half way the length of the basi occ put a cleft s outl ned traversing t at th left ( ) sphenoid-occipital syn hond o is (⟶) synchond o s betwe n basi occiput and condylar pa t of occ put at the right (↦) and part ally absent synchon drosis at the left (↝)

notochord These authors call this the parachordal cartilage or basal plate It is immediately caudal to it i e between this plate and the first cervical sclerotome that they have seen four occipital somites develop from which three typical sclerotomes derive These sclerotomes do not retain their seg mentation as in the vertebral region but fuse into a condensed mass, contin uous cranially with the parachordal condensations FRORIEP (1882 1883) was the first to describe these three to four sclerotomes forming the neo or spon dylo cranium KOLLMAN (1905) suggested that if the most caudal segment fails to fus with the remaining sclerotomes to form the occiput one can expect sign of what is called manifestation of the occipital vertebra This basioticum or os praeba ioccipitale is after KOLLMAN regarded as such a manifestation of an occipital vertebra In other mammals this basioticum was reported among oth rs by BYSTROW (1933)

Generally it is believed that the basi occiput ossifies out of one ossification



Fig. 1. Basal view (from a four year old boy). Vertical cleft in the proximal part of the basi-occiput (→) probably representing non-calcified cartilage between two ossifying centers of the basi-occiput.

contents were not investigated. This also applies to SAUSER's (1933/34) case. SAUSER speculated about the contents of these clefts in the basi-occiput, while HERVÉ, as mentioned, probably did not investigate his specimen microscopically. The few cases reported in the radiologic literature by LIST (1941), by SCHMIDT & FISCHER (1960, 1962) and by LOMBARDI (1961) were also not microscopically investigated.

During a radiologic investigation of post mortem specimens of the spheno-basi-occiput, a specimen was obtained in which a transverse cleft through the basi-occiput was present. It was felt to be of interest to investigate the structures of this cleft microscopically. The findings are reported in this paper.

Embryology. Normally, according to KEITH (1948), GRAY (1958) and BALFOUR (1881) the chondrofication of the skull begins in the second month of intra-uterine life, when the occipital bone develops from the parachordal cartilaginous bars which unite into the basilar plate. Although signs of segmentation, sclerotomes, are seen in the series of foramina through which the hypoglossal nerve roots escape, this plate never becomes segmented.

According to HAMILTON et coll. (1952) however, chondrofication of the condensed ectomeninx to form an unpaired plate-like mass occurs immediately caudal to the hypophysis in the region of the most cranial portion of the

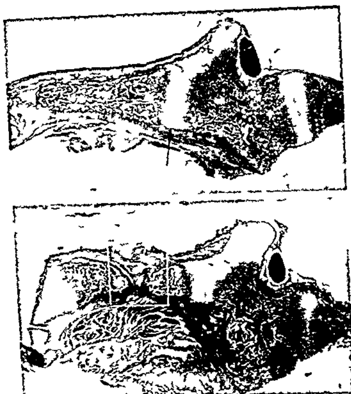


Fig 5 *Upper* ... microscopic specimen at cut of surface A (see fig 3) Normal cartilage between basisphenoid and basi occiput (arrow) *Lower* ... microscopic specimen at cut of surface B (see fig 3) The basi-occiput is divided into two (see fig 6 for magnification of the marked out area)

female infant of about 1 650 g birthweight born after 44 weeks of gestation who had a tracheo esophageal fistula and died from congenital heart disease This specimen is one of a series of 80 similar specimens taken from infants and it is the only one which presented the features as shown in the radiographed specimen (see Fig 2) The dura covering the intracranial surface was of normal colour and consistency smooth and uninterrupted Externorly no indication of a bony defect could be demonstrated

Radiographically a transverse 3 mm wide by 8 mm long cleft was demonstrated in the basi-occiput located half way between the basion and the basi sphenoid synchondrosis above the level of the jugular tubercles It extended from its left side till almost the midline In addition the roentgenogram of this specimen showed that one of the anterior foramen magnum synchondroses

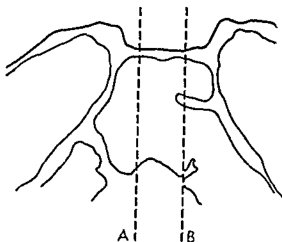


Fig. 3. Schematic drawing of specimen as seen in fig. 1; the broken lines A and B represent the levels of cuts.



Fig. 4. *Upper*: Photograph of specimen after cut A, seen from the right. Sphenoid-occipital synchondrosis (arrow); the basi-occiput is not divided. *Lower*: Photograph of specimen after cut B, seen from the right. The basi-occiput is seen divided by a vertical non-osseous partition (arrow).

center, although POIRIER & CHARPY (1899) reported the possibility of two ossification centers, lying side by side (see Fig. 1). The basi-occiput is separated from the condylar parts of the occipital bone by synchondroses which become synostosed at about the age of seven years.

Material: The specimen contained the greater portion of the basi-sphenoid bone, including the sella turcica, the basi-occiput with adjacent petrous bones, and anterior rim of the foramen magnum. It belonged to a six day old

like material in order to support the hypothesis of occipital vertebra Also at this age one would expect to find cartilage if one considers SAUSER s hypothesis who sees in the basioticum a manifestation of all the sclerotomes of the neo cranium

This cleft resembles radiologically that of the unilateral cleft from LIST (1941) What his case and the cases from SCHMIDT & FISCHER (1960 1962) and LOMBARDI (1961) with bilateral but no total clefts have in common are severe bony deformities of the cranio vertebral junction a fact already mentioned by SCHMIDT & FISCHER who observed severe occipital dysplasia in one of their three cases

It is of interest to note that in the roentgenogram of this specimen a synostosis appeared at the level of the left anterior foramen magnum synchondrosis a synchondrosis which normally is synostosed at the age of seven years Although no histologic verification of stenosis was obtained (this part of the specimen was lost) the radiographic picture strongly suggests the absence of such a synchondrosis as compared to that on the opposite side This second abnormality could lead to the suggestion that in cases of occipital dysplasia with an asymmetrical foramen magnum but without assimilation or occipitalization of C1 this asymmetry of the foramen magnum is due to a congenital fusion or prenatal synostosis of a foramen magnum synchondrosis The cleft seen in the basi occiput does not function as a displaced synchondrosis because absence of cartilage in this cleft rules out this function This early synostosis of the synchondrosis may be the explanation for the hypoplasia of the basi occiput so often encountered in occipital dysplasia

Acknowledgement

I am very much indebted to Dr W L Donohue (Director of Pathology The Hospital for Sick Children) for obtaining post mortem specimens from his department and for his advice I am also grateful to Dr Carlton G Smith (Professor of Anatomy University of Toronto) for his helpful suggestions

SUMMARY

An incomplete transverse cleft of the basi-occiput in an infant is described radiologically and microscopically This cleft consisted of fibrous tissue it had not the structures of a synchondrosis and it occurred simultaneously with a synostosis of the ipsilateral anterior foramen magnum synchondrosis

ZUSAMMENFASSUNG

Beschreibung der Radiographie und Mikroskopie einer unvollständigen Spalte des Basi Occiput eines Säuglings Die Spalte bestand aus fibrösem Gewebe Sie hatte nicht die Struktur einer Synchondrose Sie trat gleichzeitig mit einer Synostose der ipsilateralen vorderen Synchondrose des Foramen magnum auf



Fig. 6. Magnification of area from fig. 5, lower view. The two ossified parts of the basi-occiput are separated here not by cartilage but by fibrous tissue.

the left one, was obliterated. After storage in a 10 % saline formalin solution, the specimen was demineralized and prepared for routine microscopic studies.

Two cuts were made (Fig. 3). One cut was made parasagittally through the right half of the specimen. At the cut surface in Fig. 4, the basi-occiput is seen as a single bone, separated anteriorly from the basi-sphenoid by normal synchondrosis. The second cut was made parasagittally to the left of the mid-line. In contrast to the previous cut, the basi-occiput, as may be seen in Fig. 4, is divided by a vertical strip of non-osseous material. Microscopic sections are shown in Figs. 5 and 6. The tissue forming the cleft does not consist of cartilage or non-calcified bone but appears to be fibrous tissue.

Discussion

The cleft in the basi-occiput in this newborn resembles closely the clefts as reported in the literature. This is the first time that it could be stated microscopically that the cleft is actually a gap in the osseous elements of the basi-occiput filled with fibrous tissue. The absence of cartilage is probably evidence against any theory incriminating the basioticum as a so-called "occipital vertebra" arising from the most caudal sclerotome of the neocranium. At such a young age, it would be reasonable to expect cartilage or intervertebral disk

FROM THE NATIONAL CHILDREN'S CARDIAC HOSPITAL, FLORIDA, MIAMI U S A

SIZE OF ASCENDING AORTA IN CONGENITAL CARDIAC LESIONS AND OTHER HEART DISEASES

by

AGUSTIN CASTELLANOS and FRANCISCO A HERNANDEZ

Knowledge of the size of the ascending aorta is considered a valuable aid in the diagnosis of many congenital cardiac lesions especially of those involving the left side of the heart Conventional roentgenograms are however not very accurate when dealing with mild lesions especially in infancy when hypertrophy of the thymus gland is often present sometimes in association with other cardiovascular malformations

Angiocardiograms obtained after injection of the contrast medium into the right heart the left ventricle or into the aorta allow us to study in detail the sinus of Valsalva the ascending and descending aorta and the large vessels arising from this artery

Recently measurement of the ascending and descending aorta in some types of congenital heart disease have been reported (ARVIDSSON 1963), but the significance of the size of this vessel in many congenital malformations of the heart appears to have been overlooked This seems surprising because valuable diagnostic information can be expected to be obtained in advance when the vessel departs from the left ventricle

Research work described in this paper has been supported by Grant No HE-06514 03 National Institute of Health Dept of Health Education and Welfare Public Health Service Bethesda Maryland U S A Submitted for publication 12 April 1965

RÉSUMÉ

Description radiologique et microscopique d'une fente transversale incomplète du basi-occipital chez un nourrisson. Cette fente contenait un tissu fibreux, elle n'avait pas la structure d'une synchondrose et il y avait en même temps une synostose de la synchondrose homolatérale antérieure du trou occipital.

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RÉSUMÉ

Description radiologique et microscopique d une fente transversale incomplète du basi occipital chez un nourrisson Cette fente contenait un tissu fibreux elle n avait pas la structure d une synchondrose et il y avait en même temps une synostose de la synchondrose homolatérale antérieure du trou occipital

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The measurements were in all cases performed in the lateral projection In this projection only one correction factor need be used for determining the diameter of the ascending as well as the descending aorta For the film obtained in anteroposterior projection one correction factor should be used for the ascending aorta and for the film in frontal position one correction factor for the ascending and another for the descending aorta should be used due to the different distances of these vessels from the film Therefore the measurement of both the ascending and descending aorta is more precise in lateral than in anteroposterior projection The diameter at end systole is converted to cross sectional area according to the following formula

$$\frac{d(mm)}{2}^{2}\ 3\,1416$$

Correction for distortion due to geometrical magnification was made in all the cases The outer diameter of the catheter used in the procedure was measured by a micrometer The diameter of the catheter as it appears in the film was measured by a caliper and a factor was derived from the ratio of the actual and apparent diameter of the catheter

The percentage of magnification ranged from 10 % to 30 % depending on the distance from the thorax to the film which depends on the distance from the roentgenographic table to the film and on the lateral and anteroposterior diameters of the thorax

As pointed out by ARVIDSSON (1963) the aorta should be considered as being cylindrical All the results have been expressed in end systolic cross-sectional areas (cm^2)

Results

Normal cases The data obtained in the study of 14 normal cases are recorded in Table 1 A correlation between the end systolic cross sectional area of the ascending aorta and the body surface area (BSA) showed that a direct relationship existed and the linear regression equation obtained for these cases was

$$Y = a - bx = (3\,1655) \times - 0\,0844 \quad r = 0\,9913$$

the systolic cross sectional area of the ascending aorta being obtained by multiplying the body surface area with 3 16 (Fig 1)

In none of these cases were any hemodynamic abnormalities or structural changes in the cardiac chambers observed

The purpose of this paper is to report the size of the ascending aorta in 107 cases of the most frequent types of congenital heart disease, the majority involving the left side of the heart, and also to make an attempt to draw practical conclusions of diagnostic value

Material and Method Fourteen normal cases and 107 cases of congenital heart disease were studied Angiocardiograms were obtained by injecting the contrast medium low into the right atrium, into the right ventricle, or into the main pulmonary artery Counter current or selective injections into the aorta or the left ventricle were made in the usual manner A single plane or biplane Schonander apparatus was used, with a single or cross hatch grid, at a speed of 2 or 6 films per second, with a fixed tube to target distance of 36 inches (about 91 cm) Counter current aortograms were obtained by injecting the contrast medium manually, and selective injections were made utilizing a Cordis injector, with a pressure range from 300 to 700 lbs/inch² (about 136 to 318 kg/2 5 cm²) through a Lehman catheter with NIH tip and a length varying from 50 to 100 cm As contrast medium we used in most of the patients Hypaque 75 %, 1 to 1 5 ml per kilogram of weight being used for each injection which was preceded by a test dose of 2 ml injected intravenously 20 min before Simultaneous recording of the LCG and of each roentgen exposure by means of a Sanborn 4 channel Poly Viso enabled us to correlate each film with the period in the cardiac cycle at which it was taken

A tabulated summary of the material of 121 cases is given below

	Case	Age in years		BSA in m²	
	Nos	Range	Average	Range	Average
Normal	14	4 5—31 0	10 8	0 6?—2 00	1 14
Coarctation of aorta	20	0 3—37 0	11 1	0 28—1 85	1 06
Patent ductus arteriosus	20	0 6—36 0	8 1	0 33—1 52	0 8?
Aortic stenosis	24	5 0—25 0	10 4	0 67—? 10	1 ?0
Aortic insufficiency	5	9 0—50 0	22 6	0 86—1 84	1 46
Aortic stenosis and aortic insufficiency	6	6 5— 24 —	12 6	0 69—1 76	1 ?1
Aortic insufficiency and ventricular septal defect	4	5 0—14 5	11 1	0 67—1 50	1 15
Complete transposition	10	0 2—3 5	1 6	0 26—0 57	0 37
Truncus arteriosus and pseudotruncus	11	1 5—18 0	6 6	0 40—1 32	0 71
Fibroelastosis	3	0 3—0 3	0 3	0 ?4—0 28	0 26
Atrioventricular canal		4 4 5—23 0	10 1	0 45—0 90	0 66

In the majority of cases a routine cardiac catheterization was performed prior to the contrast examination Pulmonary and systemic blood flows were estimated according to the Fick principle Measurement of the ascending aorta was made at half the distance from the aortic leaflets to the origin of the innominate arterial trunk both in end systole and end diastole

Table 2

Systolic c oss sectional area of the ascending aorta in patent ductus arteriosus and coarctation of the aorta

Case Nos	Age yrs	BSA m	Systole cm	Diastole cm	Remarks
1	8 0	0 91	4 2	3 2	Coarctat on of aorta (adult type)
2	3 5	0 65	0 9	0 6	Coarctation of aorta interrupti n of aortic arch
3	8 5	0 91	3 1	2 5	
4	16 0	1 62	7 0	6 2	
5	37 0	1 85	7 4	6 2	
6	20 0	1 60	9 0	7 0	
7	8 0	0 90	4 5	4 1	
8	5 0	0 64	2 2	2 0	
9	26 0	1 55	9 0	7 0	
10	2 0	0 40	3 0		
11	9 5	1 05	4 1	3 0	Coarctation of aorta (adult type)
12	10 0	0 95	4 5	3 1	
13	15 0	1 37	4 5	3 1	
14	9 0	1 04	3 4	2 4	
15	14 0	1 56	7 0	5 3	
16	8 0	1 15	4 9	3 4	
17	2 0	0 30	2 2	1 7	
18	12 0	1 43	3.5	2 8	
19	0 3	0 28	1 3	1 0	
20	9 0	1 05	4 9	3 9	Coarctation of aorta aneurysmal d latat on of s nus and Vals lva
1	16 0	1 52	5 7	3 4	
22	12 0	1 28	7 0	4 9	
23	5 0	0 75	3 1	1 7	
24	16 0	1 35	5 7	4 9	
25	0 9	0 33	1 1	0 7	
26	1 0	0 36	2 8	1 7	
27	0 6	0 37	2 0	1 5	
28	2 5	0 42	2 0	1 1	Patent ductus a teriosus
29	13 0	1 44	6 1	4 5	
30	5 0	0 83	2.5	2 0	
31	0 8	0 39	0 6	0 3	
3	36 0	1 45	12 5	10 0	
33	1 0	0 34	0 8	0 3	
34	1 5	0 45	1 0	0 7	
35	2 5	0 60	2 1	1 8	
36	0 9	0 33	0 9	0 5	Pate t ductus arte iosus nd
37	0 0	1 41	10 7	4 1	Co ct of aorta (inf nt le type)
38	0 5	0 35	0 5	0 3	Co rct of aorta (adult typ)
39	10 5	1 19	5 7	3 4	Coa ct of aorta (infantile type)
40	17 0	1 25	1 7	1 3	Pulmonary hypertens on A S
					Pul nona y hyper res stance

Table 1

Systolic cross sectional area of the ascending aorta in 14 normal cases

Case Nos	Age yrs	BSA m²	Systole cm²	Remarks
1	31 0	1 96	6 1	Innocent murmur
2	[illegible] 5	0 78	2 5	Right sided aorta
3	4 [illegible]	0 74	2 8	Anom origin of right subclavian artery
4	11 0	1 16	3 6	Innocent murmur
5	[illegible]	0 74	2 3	Mesocardia
6	[illegible] 0	0 74	2 1	Innocent murmur
7	[illegible]	0 7[illegible]	2 [illegible]	Innocent murmur
8	8 0	0 78	2 2	Innocent murmur
9	[illegible]	0 62	1 5	Innocent murmur
10	8 0	0 88	2 [illegible]	Innocent murmur
11	18 0	1 73	[illegible]	Innocent murmur
12	16 0	1 80	[illegible] 6	Innocent murmur
13	16 0	2 00	6 2	Innocent murmur
14	13 0	1 32	4 1	Right sided aorta

Coarctation of aorta Nineteen cases of pure (adult type) coarctation of the aorta have been studied (Table 2, Cases 1 to 20) and, in addition, one case of complete interruption of the aortic arch (Case 2) This group includes one with marked aneurysmal dilatation of the sinus of Valsalva (Case 20)

Values above normal (Fig 2) were found in 18 cases (90 %), one of them was the abovementioned case of interrruption of the aortic arch

Patent ductus arteriosus Twenty cases of this disease have been considered (Table 2), three (Cases 36, 37 and 38) with association of coarctation of the aorta (two of infantile type and one of adult type), one (Case 39) with pulmo

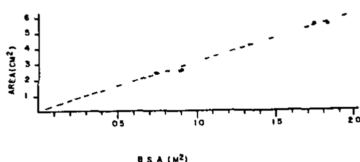


Fig 1 Normal cases Correlation between end systolic cross sectional area of ascending aorta and body surface area A direct relationship was found

Table 2

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5	37 0	1 85	7 4	6 2	
6	20 0	1 60	9 0	7 0	
7	8 0	0 90	4 5	4 1	
8	5 0	0 64	2 2	2 0	
9	26 0	1 55	9 0	7 0	
10	2 0	0 40	3 0		
11	9 5	1 05	4 1	3 0	Coarctat on of aorta (adult type)
12	10 0	0 95	4 5	3 1	
13	15 0	1 37	4 5	3 1	
14	9 0	1 04	3 4	2 4	
15	14 0	1 56	7 0	5 3	
16	8 0	1 15	4 9	3 4	
17	2 0	0 30	2 2	1 7	
18	12 0	1 43	3 5	2 8	
19	0 3	0 28	1 3	1 0	
20	3 0	1 05	4 9	3 9	Coarctation of aorta aneurysmal dilatation of sinus and Valsalva
21	16 0	1 52	5 7	3 4	
22	12 0	1 28	7 0	4 9	
23	5 0	0 75	3 1	1 7	
24	16 0	1 35	5 7	4.9	
2	0 9	0 33	1 1	0 7	
26	1 0	0 36	2 8	1 7	
27	0 6	0 37	2 0	1 5	
28	2 5	0 42	2 0	1 1	Patent ductus arterio us
29	13 0	1 44	6 1	4 5	
30	5 0	0 83	2 5	2 0	
31	0 8	0 39	0 6	0 3	
32	36 0	1 45	12 5	10 0	
33	1 0	0 34	0 8	0 3	
34	1 5	0 45	1 0	0 7	
35	2 5	0 60	2 1	1 8	
36	0 9	0 33	0 9	0 5	Patent ductus a te iosus and
37	20 0	1 41	10 7	4 1	Coarct of aorta (infantile type)
38	0	0 35	0 5	0 3	Coarct of ao ta (adult type)
39	10 5	1 19	5 7	3 4	Coarct of aorta (infant l type)
40	17 0	1 25	1 7	1 3	Pulmonary hypertens on A S
					P lmonary hyper resistance

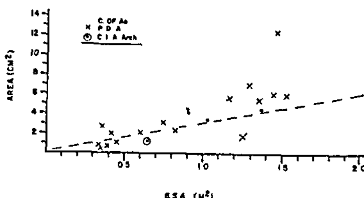


Fig. 2. End systolic cross sectional area of the ascending aorta plotted against body surface area in cases of pulmonary ductus arteriosus and coarctation of the aorta.

nary hypertension and valvular aortic stenosis, one (Case 40) complicated with high pulmonary resistance.

As may be seen from Fig. 2, six cases present values which fall below the normal regression line. It should be noted that four cases with a body surface area below 0.5 m² present values below normal, one with high pulmonary resistance was found to be below the normal regression line and the other one above. Among the 15 uncomplicated cases with left to right shunt, thirteen (86.6 %) had values above normal. The higher values were found for the largest BSA (m²), and a significant direct relationship was found between both parameters.

Aortic stenosis. Twenty four cases were analyzed (Table 3): four subvalvular (Cases 2, 3, 4, and 5), twelve valvular (Cases 6 to 17) (see also Fig. 3a), five hypertrophic muscular subaortic cardiomyopathy (Cases 18 to 22) (see also Fig. 3b), and two supravalvular (Cases 23 and 24), one of them presenting also multiple peripheral stenosis of the pulmonary artery branches. In Case 1, coarctation of the aorta was also present.

Fig. 4 shows only the cases of aortic stenosis, aortic insufficiency and association of both lesions. In general, a direct relationship was found to be present in all these anomalies when plotting the end systolic cross sectional area of the ascending aorta against the BSA (m²). All observations with valvular aortic stenosis had values which fell above the normal regression line and in many of them the results appeared far removed from the normal line. Four out of five cases of hypertrophic muscular subaortic stenosis presented normal or values below the normal. The two cases of supravalvular aortic stenosis had an aorta size below the normal, and two out of the four cases of subaortic stenosis were found to have values above the normal.

Table 3

Systolic cross sectional area of the ascending aorta in aortic stenosis and aortic insufficiency

Case Nos	Age yrs	BSA m	Ascending aorta		Remarks
			Systole cm	Diastole cm	
1	5 0	0 76	2 9	2 4	Aortic stenosis and coarctation of aorta
2	15 0	1 50	5 7	5 3	
3	9 0	0 98	2 2	1 3	Aortic stenosis subvalvular
4	7 0	1 00	4 5	3 6	
5	11 5	1 20	2 5	1 7	
6	14 0	1 62	15 7	14 2	
7	8 0	1 21	9 0	6 1	
8	12 5	1 78	11 9	10 0	
9	10 0	1 20	9 6	7 1	
10	18 0	1 90	13 8	10 1	
11	10 0	1 18	5 3	4 1	
12	6 0	0 73	5 1	3 4	Aortic stenosis valvular
13	14 0	1 57	11 9	9 4	
14	8 0	0 96	6 2	5 0	
15	9 0	1 10	5 3	3 3	
16	11 0	1 20	10 2	7 3	
17	7 0	0 84	3 1	2 2	
18	25 0	2 10	8 2	6 0	
19	9 0	1 13	3 7	2 8	
20	15 0	1 85	5 3	5 0	Aortic stenosis muscular
21	6 5	0 81	2 5	1 5	
22	6 0	0 77	1 5	0 9	
23	5 0	0 67	0 7	0 3	Aortic stenosis supravalvular
24	8 5	0 87	2 2	1 5	Aortic stenosis supravalvular
25	50 0	1 50	13 5	9 9	
26	9 0	0 86	5 3	4 0	
27	14 0	1 48	5 7	4 5	Aortic insufficiency and coarctation of aorta
28	20 0	1 63	13 1	9 0	
29	20 0	1 84	19 6	17 3	
30	24 0	1 70	11 3	9 0	
31	16 0	1 76	8 5	7 0	
32	13 0	1 30	12 0	9 0	Aortic insufficiency and aortic stenosis
33	6 5	0 74	6 2	4 9	
34	10 0	1 10	9.6	7 0	
35	6 5	0 69	6 7	5 8	
36	5 0	0 67	2 0	2 0	
37	14 5	1 50	10 0	7 0	Aortic insufficiency ventricular septal defect
38	13 0	1 01	5 0	3 2	
39	12 0	1 45	7 0	5 9	Aortic insufficiency ventricular septal defect pulmonary stenosis

In this case the aortic stenosis was associated with multiple peripheral stenosis of the pulmonary artery branches



Fig 3 a) End systole in lateral projection Aortic valvular stenosis enlarged ascending aorta Case 16 Table 3 BSA 1 20 m^2 and systolic area 10 2 cm^2 b) End systole Muscular subaortic stenosis Case 18 Table 3 BSA 2 10 m^2 and systolic area 8 2 cm^2

Pure aortic insufficiency and aortic insufficiency associated with valvular aortic stenosis This group comprised 15 cases (Table 3), four with pure aortic insufficiency, one (Case 25) associated with coarctation of the aorta, six (Cases 30 through 35) aortic insufficiency with significant valvular aortic stenosis, four (Cases 36 through 39) associated with ventricular septal defect, the latter also having valvular pulmonary stenosis

All cases of pure aortic insufficiency, and all those of this lesion associated with a significant degree of valvular aortic stenosis, were found to have a very enlarged ascending aorta, as shown in Fig 4 The largest values correspond to a case of pure aortic insufficiency

It is evident that the highest values are among the observations with high BSA (m^2)

Complete transposition of the great vessels Ten cases have been studied (Table 4), all with ventricular septal defects and six of them associated with this lesion and atrial septal defect Four cases underwent surgery autopsy was carried out in three cases

In Fig 5, the BSA (m^2) is plotted against the end systolic cross sectional area of the ascending aorta in cases of complete transposition of the great

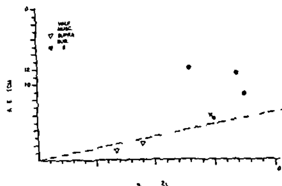


Fig 4 Plotting of the end systolic cross-sectional area of the ascending aorta against body surface area in cases of aortic diseases The supravalvular aortic stenoses present low values as well as cases of hypertrophic muscular subaortic stenosis

vessels truncus arteriosus communis and pseudo truncus A significant direct relationship appears to exist between both parameters This scatter diagram reveals that all the cases of complete transposition of the great vessels presented values above the normal regression line except one (Case 9) an infant of 2 months of age (Fig 6)

Truncus arteriosus communis and pseudotruncus Nine cases of the former were considered and two of the latter (Table 4)

Among the cases of truncus arteriosus three had a right sided aorta and one (*Case 11*) was exceptional having a huge aneurysm of the ascending aorta The BSA (m^2) was 1 32 m^2 at 18 years of age and the cross sectional area of the vessel was 45 3 cm^2, the normal for this body surface area being only 4 09 cm^2 (Fig 7)

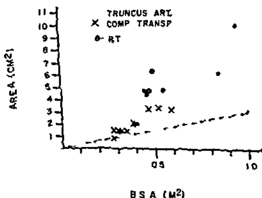


Fig 5 End systolic cross sectional area of ascending aorta in cases of truncus arteriosus communis and complete transposition of the great vessel plotted against body surface area In complete transposition the BSA values are below 0 6 m and in truncus arteriosus they [illegible] as 0 9? m Regression line is represented by dashes

Table 4

Systolic cross sectional area of the ascending aorta in complete transposition of the great vessels, truncus and pseudotruncus arteriosus, and other diseases

Case Nos	Age yrs	BSA m^2	Ascending aorta		Remarks
			Systole cm^2	Diastole cm^2	
1	1.5	0.39	2.0	1.5	Complete transposition of great vessels, ventricular septal defect and atrial septal defect
2	1.0	0.35	1.3	0.9	
3	3.5	0.30	1.3	0.7	
4	0.6	0.29	1.2	0.7	
5	3.5	0.47	3.1	2.5	
6	3.0	0.57	3.1	2.2	
7	0.5	0.34	1.3	0.9	Complete transposition of great vessels and ventricular septal defect
8	0.2	0.27	1.2	0.9	
9	0.2	0.26	0.6	0.4	
10	2.5	0.52	3.1	2.2	
11	18.0	1.32	15.3	40.0	Truncus arteriosus with aneurysm
12	5.5	0.84	6.1	3.4	Truncus arteriosus
13	13.0	0.90	10.1	—	
14	13.0	0.95	10.0	—	
15	1.5	0.45	4.9	3.4	
16	3.5	0.55	4.9	3.4	
17	3.0	0.60	5.3	4.1	Truncus arteriosus and right sided aorta
18	2.0	0.40	2.0	1.3	
19	10.0	0.85	8.0	4.0	
20	2.0	0.46	4.9	3.7	Pseudotruncus arteriosus
21	2.0	0.49	6.4	3.2	
22	0.3	0.24	0.7	0.5	Fibroelastosis of the left ventricle
23	0.3	0.28	0.5	0.4	
24	0.3	0.27	1.0	0.7	
25	4.5	0.64	7.0	5.3	Atrioventricular canal and aortic stenosis (valvular)
26	23.0	0.45	1.5	1.3	Atrioventricular canal
27	8.0	0.90	3.5	1.8	
28	5.0	0.68	1.5	1.1	

Fig. 6 reveals that all the observations of truncus arteriosus fall above the normal regression line. The two cases of pseudotruncus arteriosus were found to have areas far removed from the normal regression line and it is interesting to note that the values for the latter malformation fall further away from the values for the complete transposition of the great vessels (Fig. 8).

Miscellaneous cases Table 4 includes three cases of fibroelastosis of the left ventricle and four with endocardial cushion defect One of the cases presented in addition valvular aortic stenosis

The size of the ascending aorta in fibroelastosis appears to be at the normal regression line, or above or below but always very close to this line One case of atrioventricular canal presented a value very high for the area of the aorta but aortic valvular stenosis was present (Case 25) The systolic area was 7 0 cm² while the normal value for BSA in this case (0 64 m²) was 2 cm² In the remaining cases two presented normal or below normal areas and one a slightly increased area

Discussion

Patent ductus arteriosus (PDA) The size of the aorta in patent ductus arteriosus has been a controversial matter While STAUFFER (1949) and SHAPIRO (1949) stated that the aorta was normal in a series of 90 cases studied with conventional radiography others emphasized that the ascending aorta is dilated HEIM DE BALSAC (1954) also encountered enlargement of the ascending aorta in 57 % of cases SALTZMAN (1954) described 34 out of 47 adults with definite aortic enlargement, and KEATS & STEINBACH (1955) found enlargement of the aorta only in 11 out of 100 cases DOTTER & STEINBERG (1951) using venous angiocardiography focused their attention on localized dilatation of the aorta distal to the origin of the left subclavian artery (as described by GRISHMAN STEINBERG & SUSSMAN) KJELLBERG et coll (1959) found that 49 out of 115 cases presented dilatation of the aorta Recently ARVIDSSON (1963) studied 12 cases of patent ductus arteriosus without pulmonary hypertension using angiocardiography Five of them were found to have high values of systolic areas while two had areas lying a little remote from the PDA regression line but close to the normal regression line In spite of these findings ARVIDSSON believes that the size of the ascending aorta in most cases of PDA should be considered normal

Our results favor the generalized criteria that enlargement of this vessel is very common in this disease The disparity of opinions may be explained by factors which influence the size of the ascending aorta the most important being shunt across the ductus

Coarctation of the aorta The size of the ascending aorta in coarctation has not been widely considered BROWN (1950) described it as 'commonly dilated and projecting to the right ARVIDSSON does not discuss this disease in the previously mentioned paper DOTTER & STEINBERG on the basis of venous angiocardiography found in the levo phase that the ascending aorta usually



Fig 6 Peripheral intravenous angiocardiography in lateral projection Complete transposition of the great vessels Ascending aorta quite anteriorly situated and no right to left shunt at atrial level Case 9 *Table 4 BSA 0 26 m² and systolic area 0 6 cm²*



Fig 7 Injection of contrast medium into ascending aorta Truncus arteriosus communis with huge aneurysm of the ascending aorta the left main pulmonary artery is not seen because it is superimposed on the lower part of the ascending aorta Case 11 *Table 4 BSA 1 32 m² and systolic area of aorta* 45 3 cm

but not always, seems to be dilated from a slight to a marked degree We have found different degrees of enlargement in 90 % (18 out of 20) of our cases (Fig 2)

The present study shows that coarctation of the aorta should be considered as a disease that is commonly accompanied by an enlarged ascending aorta The severity of the stenosis, the preductal or postductal situation of the narrowing, and the patency of the ductus arteriosus, when present, are in this disease related to the size of this part of the aorta

Complete transposition of the great vessels The size of the aorta has not been stressed in this malformation HEIM DE BALSAC et coll (1954) described it as generally being of normal size BROWN (1950) stated that it is normally developed, KJELLBERG et coll (1959) found it moderately dilated in several cases, KEITH (1958) stated that in 97 % of the cases the aorta was equal in size to the pulmonary artery but in one exceptional case it was larger We found that in our series of cases, in six out of nine, the size was so slightly enlarged that without performing angiocardiography it should be considered



Fig 8 Intracardiac injection in frontal position Truncus arteriosus communis right sided aorta main pulmonary branches poorly outlined Case 17 Table 4 BSA 0 60 m and systolic area 5 3 cm

within normal limits In three cases (30 %) only was a significant enlargement found

The conclusion may be drawn that the size of the ascending aorta should be considered slightly or moderately enlarged in this malformation The normal or stenosis pulmonary artery or a significant right to-left shunt at the atrial level seem not to play an important role in affecting the size of the ascending aorta

Truncus arteriosus communis and pseudotruncus In contrast to the situation with complete transposition considerable attention has been devoted to the size of the ascending aorta in studies on truncus arteriosus NADAS (1963) considered the aorta to be enlarged TAUSSIG (1960) emphasized that it is a single vessel of abnormally large caliber KJELLBERG et coll found aortic enlargement although the group comprised older patients two of them being 13 years and another one 18 years old All our cases with these diseases presented a large aorta in some of the observations with values far removed from the normal regression line

According to these findings the ascending aorta should be described as dilated in the two above mentioned anomalies and both are accompanied

by an aorta whose caliber is far greater than in complete transposition This point appears to be of great value for differentiating between these anomalies

Aortic stenosis Progress in surgery has forced radiologists to differentiate the anatomical types of aortic stenosis When correlated with the size of the aorta, several interesting observations have been made Our results agree with those of other authors (CAMPBELL et coll 1953, DOWNING 1956, GRISHMAN et coll 1947, KEATTE et coll 1939), establishing that in all cases of valvular aortic stenosis, as well as in all those cases in which significant valvular stenosis is associated with aortic insufficiency, the systolic caliber of the ascending aorta is above the normal We also have found confirmation of the fact emphasized by earlier authors who state that the caliber of this vessel appears normal or smaller than normal in hypertrophic subaortic muscular stenosis (BRAUNWALD et coll 1960, DOTTER et coll 1961) as well as in cases of supravalvular aortic stenosis (BEUREN et coll 1962, BRAUNWALD et coll, MORROW et coll 1959) The size of the ascending aorta in subaortic stenosis may according to our results be smaller or larger than normal, although some authors have found the vessel to be enlarged in the majority of cases

Aortic insufficiency Striking enlargement of the ascending aorta was found to be present in all the cases studied and a huge aneurysmal dilatation was found in one case (systolic cross sectional area 19 6 cm², the normal for this observation being 6 cm² Since slight as well as severe cases have been considered in our series the conclusion may be drawn that dilatation of the ascending aorta is a constant feature with this lesion Obviously, enlargement of this vessel due e g to syphilitic aortitis and atherosclerosis have not been considered in this paper

Other diseases In regard to fibroelastosis of the left ventricle, all our cases were represented by infants The size of the vessel was found to be smaller than normal and we assume that this is consistent with the low systemic flow present in all of them With respect to endocardial cushion defect, those with the largest left to right shunt have a smaller ascending aorta, except when valvular aortic stenosis is present

Conclusion

The end systolic cross sectional area of the ascending aorta in 14 normal cases and 107 cases of different types of congenital heart disease have been plotted against the BSA (m²)

1 In 15 uncomplicated cases of patent ductus arteriosus (86 6 % of the

cases) and in 18 cases (90 %) of pure coarctation of the aorta, the ascending aorta was found to be enlarged

2 In 10 observations of complete transposition of the great vessels (30 % of the cases), and in 11 of truncus arteriosus communis and pseudotruncus (100 % of cases), the ascending aorta was very enlarged In the latter, the size of the aorta was bigger than in the former

3 In 5 cases (100 %) of pure congenital aortic insufficiency and in 6 cases (100 %) of aortic insufficiency associated with aortic stenosis the ascending aorta was found to be very large

4 In 12 cases (100 %) of valvular aortic stenosis all of them presented an aorta size above the normal value In 4 out of 5 cases (80 %) of hypertrophic muscular subaortic stenosis the caliber of the vessel was normal or below normal, the same applies to the 2 cases of supravalvular aortic stenosis Two out of 4 cases (50 %) of subaortic stenosis were found to have an aorta of size below the normal

5 The assessment of the end systolic area of the ascending aorta appears to be of value for the diagnosis of transposition of the great vessels truncus arteriosus communis pseudotruncus, different types of aortic and subaortic stenosis aortic insufficiency coarctation of the aorta and patent ductus arteriosus

6 Conventional venous angiocardiograms as well as left ventriculograms and ascending aortograms are very useful for outlining the ascending aorta, and a normal value of BSA (m^2) is the best reference for determining the size of this vessel when a normal regression line has previously been obtained

SUMMARY

The size of the aorta, assessed by its end systolic cross sectional area was determined in normal human subjects and in a group of patients with congenital cardiac lesions Interesting results were obtained indicating that the value of the roentgenologic diagnosis may be increased by an evaluation of the information obtainable by such measurements

ZUSAMMENFASSUNG

Es wurde die Grosse der Aorta in ihrem endsystolischen Querschnitt bei normalen Menschen und bei einer Gruppe von Patienten mit kongenitalen Herzfehlern bestimmt Die Resultate sind interessant da sie in Verbindung mit anderen Symptomen den rontgendiagnostischen Wert aufzeigen

RÉSUMÉ

L auteur a mesuré la surfac de la lumière aortiqu a la fin de la systole chez des sujets normaux et dans un groupe de cardiopathies congénitales Les résultats sont intéressants montrant que cette mesure contribue a augmenter l intérêt du diagnostic radiologique

by an aorta whose caliber is far greater than in complete transposition This point appears to be of great value for differentiating between these anomalies

Aortic stenosis Progress in surgery has forced radiologists to differentiate the anatomical types of aortic stenosis When correlated with the size of the aorta, several interesting observations have been made Our results agree with those of other authors (Campbell et coll 1953, Downing 1956, Grishman et coll 1947, Keatte et coll 1939), establishing that in all cases of valvular aortic stenosis, as well as in all those cases in which significant valvular stenosis is associated with aortic insufficiency, the systolic caliber of the ascending aorta is above the normal We also have found confirmation of the fact emphasized by earlier authors who state that the caliber of this vessel appears normal or smaller than normal in hypertrophic subaortic muscular stenosis (Braunwald et coll 1960, Dotter et coll 1961) as well as in cases of supravalvular aortic stenosis (Beuren et coll 1962, Braunwald et coll, Morrow et coll 1959) The size of the ascending aorta in subaortic stenosis may according to our results be smaller or larger than normal, although some authors have found the vessel to be enlarged in the majority of cases

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FROM THE DEPARTMENT OF THORACIC RADIOLOGY (DIRECTOR BJÖRN NORDENSTRÖM) AND THE DEPARTMENT OF INTERNAL MEDICINE (DIRECTOR STIG BJÖRKMAN) KAROLINSKA SJUKHUSET, STOCKHOLM

CALIBRE OF THE INFERIOR VENA CAVA IN CIRRHOSIS OF THE LIVER

by

BJÖRN NORDENSTRÖM and ÅKE NORHAGEN

It has been shown by pressure measurements of the intraabdominal and intrathoracic parts of the inferior vena cava in chronic liver disease that an increased pressure gradient exists between these parts of the vena cava in about one third of cases examined (WINKLER, TYGSTRUP & HANSEN 1959). PETERSEN, TYGSTRUP & WINKLER examined the inferior vena cava in 3 normal patients, one with bronchial asthma, one with chronic bronchitis and one with a fatty liver and also in 4 patients with hepatic cirrhosis. About 40 ml Urografin 76 % were injected within 3 seconds into the inferior vena cava slightly distal to the termination of the hepatic veins; five a.p. and lateral views were obtained at a frequency of one exposure per second, the breath being held during the exposure (no Valsalva manoeuvre).

These examinations revealed a narrowing in chronic liver disease of the subdiaphragmatic part of the inferior vena cava in relation to its intrathoracic part, and it was assumed that this was due to pressure of the liver on the vein. The constriction was considered to be the cause of the earlier observed increased pressure gradient between the intraabdominal and intrathoracic parts of the inferior vena cava.

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tion However such a reflux occurs only to a slight extent or not at all, if the respiratory movements are small or if they have been completely suspended by means of Celocurine (Vitrum) The reflux to the hepatic veins that normally occurs in connection with forced respiration and the constriction of the inferior vena cava at the diaphragm level presumably constitute important factors in the regulation of the venous return to the heart (NORDENSTROM & NORHAGEN 1965) Apart from the variations in calibre of the vein at the level of the diaphragm there are considerable variations synchronous with the respiration at the level of the liver as well as in the intrathoracic part of the vein synchronous with the heart beats and with respiration

The same constrictions of the vena cava, and reflux to the hepatic veins that are connected with forced respiration in the dog have also been recorded in man (NORHAGEN 1963)

PETERSEN et coll in their investigations instructed the patients to hold their breath without performing Valsalva s manoeuvre There do not, however, seem to have been any controls to ensure that these instructions were properly carried out Even relatively small changes in the intrathoracic and intra abdominal pressures may considerably alter the calibre of the vena cava Since moreover the flow of blood through the liver is generally reduced in cirrhosis of the liver this factor may also affect the calibre of the inferior vena cava between the site of termination of the hepatic veins and the right atrium The intrathoracic part of the inferior vena cava was compared in the above mentioned measurements with the subdiaphragmatic part of the vein

The present investigation was concerned with a comparison of the inferior vena cava in 5 cases of cirrhosis of the liver and 13 cases that were considered normal Particular attention was paid to the effect of the respiration upon the calibre and comparisons were made between the width of the subdiaphragh matic part of the inferior vena cava at the level of the liver and the width of the part located below the point at which the latter is joined by the hepatic veins

Material The controls consisted of 13 cases None of these was suffering from liver disease cardiovascular disease, or any affection that might reasonably have any bearing upon the assessment of normal variations in the calibre of the vena cava Respiration tests produced normal results

The cirrhosis cases consisted of 3 men and 2 women Some of the results of the laboratory investigations including histology are given in Table 1 The histologic examination indicated that there were only slight cirrhotic changes in Case 5 no histologic diagnosis was made in Case 1 The laboratory investigations however suggested that advanced cirrhotic changes were present in the liver in all the five cases

Table 1

Results of laboratory and histologic investigations — Bilirubin upper normal limit 10 mg/l Thymol turbidity test upper normal limit 4 units Alkalaline phosphatase upper normal limit 12 units/ml PP Prothrombin proconvertin normal range 80—120 % GOT Glutamic oxalacetic transaminase upper normal limit 40—50 units/ml GPT Glutamic pyruvic transaminase upper normal limit 35—45 units/ml BSP bromsulphthalein excretion (dose 5 mg/kg) 45 min retention value, normal < 3—4 %

No pat	Bilirubin mg/l	Thymol turbidity units	Alkaline phosphatase units/ml	PP %	GOT units per ml	GPT units per ml	BSP %	Paper electrophoresis: Hypoalbum	Paper electrophoresis: Hypergammaglob	Paper electrophoresis: Normal	Histol verific	Comments
I	21	3.5	15	25	30	52		+	+			Ascites previously no palp liver
II	10	10	3	75	50	21	16			+	Operat	Enlarged liver oesophag varices marked cirrhosis
III	22	1	22	96				+	+		Operat	No palp liver ascites oesophag varices marked cirrhosis
IV	2.8	8	8	72	20	21		+	+		Laparoscopy	Enlarged liver ascites marked cirrhosis
V	14	1	6	63	30	47	8.9		+		Laparoscopy	Enlarged liver obesity slight cirrhosis

The various hemodynamic and roentgenologic aspects of the inferior cava both in dog and man were discussed in an earlier investigation by one of the present writers (NORHAGEN 1963) These studies afforded clear evidence that the calibre of the vein varies considerably with the respiration

In the dog, during the maximum phase of inspiration, marked constriction of the vein occurs as it passes through the diaphragm, whereas during expiration this region rapidly opens up to about the same width as other parts of the vein With forced respiration, and when contrast medium has been injected into the intraabdominal part of the inferior vena cava, there is also normally a considerable reflux of contrast medium to the hepatic veins during expira

Method The examinations were as a rule carried out with the patients supine but in some also in the standing or sitting positions or sitting while cycling

A yellow Ödman catheter was introduced into the lower part of the inferior vena cava via the femoral vein under local anesthesia and contrast medium (Urografin 76 %) was injected in an amount of 1 5 ml per kg bodyweight in the course of 4 to 5 seconds Simultaneous anteroposterior and lateral views, at a frequency of 6 exposures per second in each projection were obtained during the injection The filming was also continued after conclusion of the injection over a period of about 8 seconds The patient was made to execute forced respiratory movements during the whole procedure the respiration being controlled as follows A small catheter provided with a balloon and inserted in the oesophagus recorded the intra-oesophageal pressure variations The respiration was also recorded by measuring the movements of the dia phragm in the roentgenograms The pressure variations in the oesophageal balloon an electrocardiographic tracing the beginning and end of the contrast injection and the time of exposure of the roentgenograms were all recorded on photographic paper

The measurement of the calibre of the inferior vena cava was made trans versally at the level of the upper margin of Th 12 in all cases but two in which it was made at the level of the upper margin of L1 The calibre variations in the vena cava at these sites were then compared with the corresponding variations in the vena cava about 2 to 3 cm below the point at which the latter is joined by the hepatic veins (at the level of the lower margin of L 3) Control sagittal measurements of the calibre variations of the inferior vena cava were the anteroposterior roentgenogram

Observations

Normal material Three anteroposterior roentgenograms of the contrast filled vena cava in three different phases of respiration in the normal Case 8 are shown in Fig 1 together with a sketch of the rib movements movements of the diaphragm and of the lower right margin of the liver as well as calibre variations of the vena cava as it passes behind the liver The drawing was directly copied from roentgenograms the roentgenograms selected correspond to the film exposures marked on the movement curve of the diaphragm The movements of the vena cava diaphragm ribs and margin of the liver were copied from roentgenograms corresponding to Figs 1 2 and 3 It may be seen from Fig 1b that the upper part of the vena cava is almost completely occluded as it passes through the diaphragm and even more constricted at the same



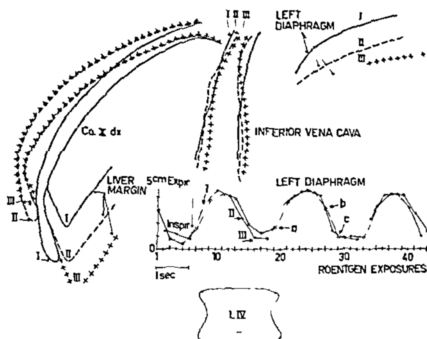


Fig 1 Passage of contrast medium through a normal inferior vena cava The vein is markedly constricted at the level of the diaphragm during maximum inspiration but becomes distended during expiration

Method The examinations were as a rule carried out with the patients supine but in some also in the standing or sitting positions or sitting while cycling

A yellow Ödman catheter was introduced into the lower part of the inferior vena cava via the femoral vein under local anesthesia and contrast medium (Urografin 76 %) was injected in an amount of 1 5 ml per kg bodyweight in the course of 4 to 5 seconds Simultaneous anteroposterior and lateral views at a frequency of 6 exposures per second in each projection were obtained during the injection The filming was also continued after conclusion of the injection over a period of about 8 seconds The patient was made to execute forced respiratory movements during the whole procedure the respiration being controlled as follows A small catheter provided with a balloon and inserted in the oesophagus recorded the intra oesophageal pressure variations The respiration was also recorded by measuring the movements of the dia phragm in the roentgenograms The pressure variations in the oesophageal balloon an electrocardiographic tracing the beginning and end of the contrast injection and the time of exposure of the roentgenograms were all recorded on photographic paper

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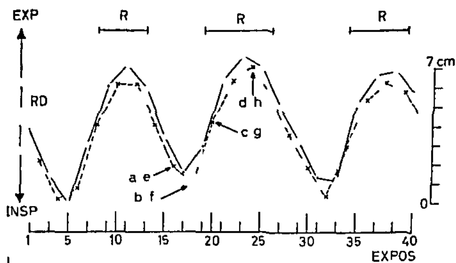


Fig 2 Normal variations in the inferior vena cava during forced respiration

site in Fig 1c These roentgenograms correspond to the later part of inspiration while Fig 1a was made at the beginning of expiration The vena cava is wide as it passes through the diaphragm in Fig 1a Lesser but quite distinct variations in calibre are also present in those parts of the inferior vena cava that lie at the level of L1 as well as below L3

Fig 1 also reveals a region with blurred outlines in the middle part of the vena cava This is caused by contrast free blood streaming in from the hepatic veins The part of the vena cava situated behind the liver is transversally narrower in its upper part than in the lower in all respiratory phases (Fig 1, sketch) During inspiration the constriction in the upper part is very marked and at the same time the lower part of the vena cava is somewhat more distended than during expiration The impression is conveyed that there is some stasis in the lower part of the vena cava due to the marked constriction at the level of the diaphragm

A typical phenomenon in the examination of the inferior vena cava in normal cases during forced respiration is produced by the expiratory refluxes to the hepatic veins Such a reflux (normal Case 5) is shown in Fig 2 (a+e) The patient was examined supine and the inferior vena cava was constricted at the level of the liver during the late phases of inspiration When inspiration was completed (b + f) the contrast medium was apparently entirely pressed out from the vena cava at the level of the liver In the middle phase of expiration (c + g) the vena cava is already distended again, after which there is a reflux to the hepatic veins (d + h) In the lateral roentgenograms of Fig 2 (e f g and h) the vena cava is narrow at the level of the liver in a sagittal direction during inspiration but considerably distended during expiration

Pathologic material The roentgenograms of one of the cases of liver cirrhosis (cirrhotic Case 2) are reproduced from the inspiratory phase in Fig 3 and during expiration in Fig 4 The movements of the ribs and diaphragm and the calibre variations of the vena cava are seen in the sketches which represent copies from the roentgenograms

It is not possible during the whole inspiration phase (Fig 3) to measure the width of the vena cava just below its passage through the diaphragm owing to blood streaming in from the hepatic veins and causing a dilution in the contrast medium Contrast dilutions in the same case may be observed in the upper right part of the vena cava during expiration (Fig 4) These are however considerably less marked than during inspiration Although very strong respiratory movements of the diaphragm were present there were no refluxes to the hepatic veins Furthermore as indicated by PETERSEN et coll the inferior vena cava appears to be narrow



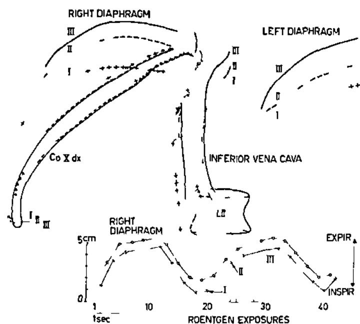


Fig 3 Advanced cirrhosis of the liver Blood streams from the hepatic veins to the right aspect of the inferior vena cava during the whole phase of respiration result in dilution of the medium



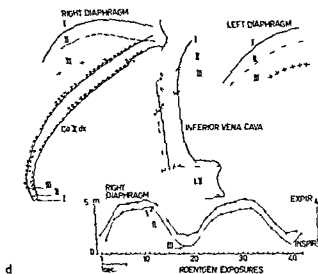


Fig 4 Blood streams f om the hepatic ve ns to the inferior vena cava during exp ration No reflux of medium to the hepatic ve ns

Table 2

Measurements of calibre variations in vena cava during inspiration and expiration in the 13 normal cases

No	Examination	Respiration phase	Minimal and maximal caval width (mm)				Reflux to liver veins
			Frontal projection		Lateral projection		
			Th 12	L 3	Th 12	L 3	
1	Supine	Inspir	—	—	28	31	
		Expir	—	—	32	30	+
2	Supine	*Inspir*	—	—	*8*	*20*	
		Expir	—	—	27	26	+
3	Supine	Inspir	18	26	26	26	
		Expir	27	26	29	25	+
4	Supine I	Inspir	25	26	—	—	
		Expir	33	30	—	—	+
	Supine II	Inspir	23	25	9	24	
		Expir	27 5	27	17	23	+
5	Supine	Begin of expir	44*	45	28	27	
		End of expir	39	43	18	26	+
		Begin of inspir	31	36	28	31	
		End of inspir	0 contr	37	0 contr	32 5	
	Sitting	Begin of inspir	36	38	45	37	
		End of inspir	25	33	28	33	
		Begin of expir	39	36	42	41	+
6	Standing	End of inspir	14*	29	23	25	
		Begin of expir	26	27	31	25	+
		End of expir	29	35	35	31	+
7	Supine	End of inspir	27	31	31	28	
		Begin of expir	31	31	36 5	34 5	
		End of expir	29	35	35	31	+
8	Supine	Inspir	10	20	—	—	
		Expir	19	26 5	—	—	+
9	Supine	End of inspir	19	28	—	—	
		Begin of expir	29	35	—	—	
		End of expir	20	30	—	—	+
	Cycling (sitting)	Inspir	23	31	25	29	
		Expir	29	32	28	27	+
10	Standing	Inspir	24	38	—	—	
		Expir	34	30	—	—	+
13	Standing	Inspir	24	25	30	28	
		Expir	25	25	31	32	+

Table 3

Transverse calibre of the vena cava during inspiration

No	Examination	Respiration phase	Width (mm) of vena cava				Reflux to liver veins
			Frontal projection		Lateral projection		
			Th 12	L 3	Th 12	L 3	
	Supine	Inspiration	24	26	—	—	
I		Expiration	27	33	—	—	0
	Standing	Inspiration	22	33	—	—	
		Expiration	22	32	—	—	0
II	Supine	Inspiration	16	27	13	25	
		Expiration	22	32	20	23	0
III	Cycling (sitting)	Inspiration	15	25	—	—	
		Expiration	26	19	—	—	0
IV	Supine	Inspiration	9	26	13	22	
		Expiration	9	26	20	20	0
V	Supine	Inspiration	18	25	—	—	
		Expiration	25	27	—	—	(+)

The schematic drawings in Figs 3 and 4 indicate that the inferior vena cava at the liver level undergoes some variations in its transverse diameter *in the* different respiratory phases In the case of marked cirrhosis however the variations in calibre appeared to be considerably less prominent than those in *the normal* case This distension of the vena cava gives it an almost spool shaped appearance in the lateral projection The diaphragm movements are *shown in Fig* 2 The arrows indicate from which phases the frontal and lateral films were selected and R signifies the *periods of time* for the occurrence of reflux from the vena cava to the hepatic veins It will be observed that these refluxes recur cyclically and synchronously with respiration and that they begin in the first *part of expiration*

Table 2 presents the measurements of the calibre variations in the vena cava during inspiration and expiration *in the* 13 normal cases It emerges from this table that a reflux of contrast medium from the inferior vena cava to the hepatic veins occurred in all cases and *without* exception during expiration It is difficult to make a direct analysis of other values in the table and the figures will therefore be converted *to more* suitable terms in connection with the comparison with the cases *of cirrhosis* It may also be seen that the inferior vena cava in 5 cases has the largest calibre at the level of L3 during inspira

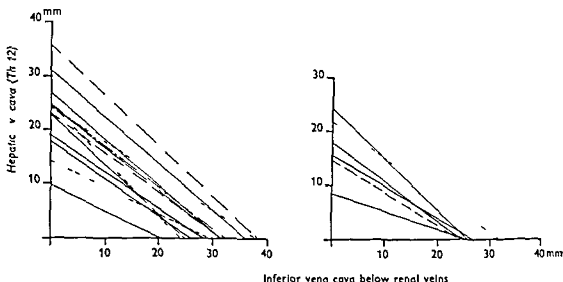


Fig 5 Transverse diameter of inferior vena cava on inspiration in normal cases (left diagram) and in liver cirrhosis (right diagram) recumbent (————) standing (- - - -) sitting (— —) and cycling (— — —)

tion (Cases 1, 3, 4, 9, and 10) During expiration, however, this calibre is less than in the region of the liver Some degree of stasis in the inferior vena cava below the liver region during inspiration may therefore be indicated

The transverse and sagittal widths of the vena cava are given in Table 3, like they were given earlier for the 13 normal cases A scrutiny of the primary material in the cirrhotic cases reveals that the reflux of contrast medium to the hepatic veins during expiration occurred only in Case 5, the cirrhosis of the liver, was, according to the microscopic examination, minimal The observed reflux to the hepatic veins was very slight, despite large movements of the diaphragm during respiration

Comparison between variations in the vena cava calibre in normal and cirrhotic cases The dimensions of the vena cava in the two groups are tabulated in Figs 5 to 8 in order to facilitate a comparison between the measurements carried out in the normal and cirrhotic materials respectively In this connection the diameter of the vena cava at the level of Th 12 is marked in along the x axis, and its diameter at the level of the lower margin of L3 along the y axis

The values of the transverse calibre of the vena cava during inspiration are given in Fig 5 A very small transverse vena cava diameter at the level of the liver is present in a case of the cirrhotic group The other cirrhotic cases appear to have a somewhat smaller transverse vena cava diameter, at the levels both

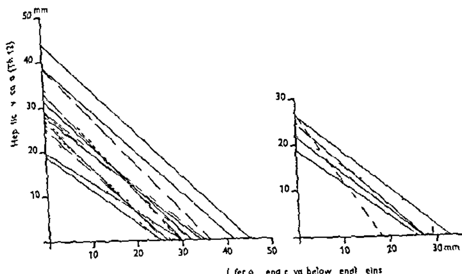


Fig 6 Transverse diameter of inferior vena cava on expiration in normal cases (left diagram) and in liver cirrhosis (right diagram) recumbent (———) standing (– – –) sitting (— —) and cycling (— —)

of the liver and the lower margin of L3 and a relatively smaller calibre at the level of the liver than at the level of the lower margin of L3

A corresponding presentation of the values of the transverse vena cava diameter during expiration is given in Fig 6 The sagittal calibre variations are compared during inspiration in Fig 7 and the sagittal diameter variations of the vena cava during expiration in Fig 8

As to the four comparisons thus made it may be stated that at the most the same conclusions as were drawn in the case of Fig 5 may apply to the others This is mainly due to the small number of cases in both groups A comparison of all the four groups also reveals that the calibre of the inferior vena cava varies in different respiratory phases at all the measuring points both in the normal and in the cirrhotic cases

Discussion

The fairly considerable variations in calibre reported earlier in the dog in different phases of respiration seem also to occur in man This holds for the normal material of 13 cases now presented as well as for the 5 cases of cirrhosis of the liver The maximum calibre of the vena cava is reached during expiration and the reflux to the hepatic veins appears to be a regularly recurring

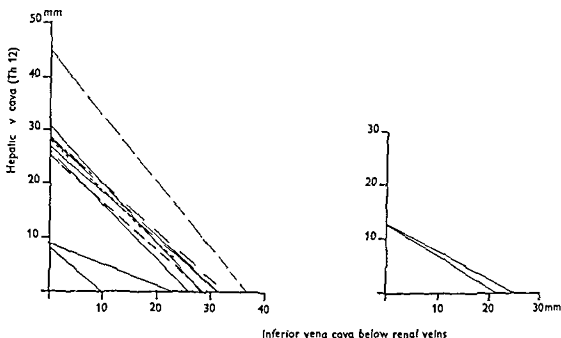


Fig 7 Sagittal diameter of inferior vena cava on inspiration in normal cases (left diagram) and in liver cirrhosis (right diagram) recumbent (————) standing (- - - -) sitting (— —) and cycling (— — —)

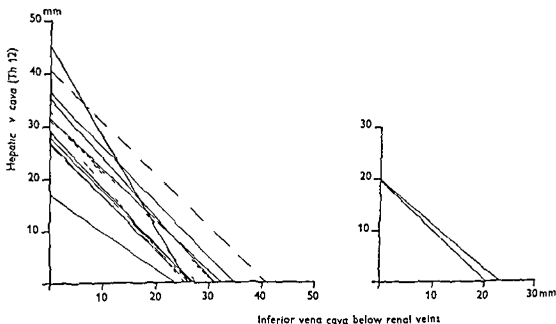


Fig 8 Sagittal diameter of inferior vena cava on expiration in normal cases (left diagram) and in liver cirrhosis (right diagram) recumbent ————) standing (- - -) sitting (— —) and cycling (— — —)

phenomenon during expiration in those normal cases in which the examination is carried out during forced respiratory movements Calibre variations in the vena cava occur in the same way in cases of cirrhosis as in the normal cases but among the former the vein at the level of the liver appears to be relatively narrower in comparison to the latter than is the part located below the liver

A comparison of the absolute diameter at the level of D12 or L1 in the cirrhotic cases with that in the normal cases disclosed that a few of the former closely resemble several of the normal cases

Some correlation with reference to the size of the subject is probably necessary for a comparison of the calibre of the vena cava between the normal and pathologic material The correlation factor that should be used in this connection cannot yet be determined The size of the vena cava should possibly bear a relationship to the blood volume of the subject

The most characteristic difference between the cases of cirrhosis and those that are normal is the absence of reflux of contrast medium from the inferior vena cava to the hepatic veins in cases of advanced cirrhosis Such refluxes are regularly found in all the normal cases in which the examination is carried out during forced respiratory movements This is in itself not surprising during deep inspiration the diaphragm is pushed downwards so that a part of the blood pool in the normal liver is presumably pressed out Prerequisites thus exist during expiration for a retrograde contrast filling from the inferior vena cava to the central parts of the hepatic veins The function of the liver as a blood depot is probably reduced in cirrhosis and as the liver is fibrotic it would not be readily compressed by a downward movement of the diaphragm It would therefore follow that any evacuation of hepatic venous blood would be unlikely to be produced by respiration

SUMMARY

Cavography during forced respiration in 13 normal cases has been compared with corresponding investigations in 5 cases of cirrhosis of the liver The changes in calibre of the inferior vena cava are described and their significance is discussed

ZUSAMMENFASSUNG

Die Cavographie mit Pressatmung in 13 normalen Fallen wurde mit entsprechender Methodik an 5 Fallen von Leberzirrhose verglichen Die Veranderungen in der Weite der Vena cava inferior werden beschrieben und deren Bedeutung erörtert

RÉSUMÉ

Les auteurs ont comparé la cavographie au cours de la respiration forcée chez 13 sujets normaux et chez 5 malades atteints de cirrhose du foie Ils décrivent les modifications du calibre de la veine cave inférieure et examinent leur intérêt

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FROM ROENTGEN DEPARTMENTS I II AND III AND SURGICAL DEPARTMENT I
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ANGIOGRAPHY IN PRIMARY HEPATIC CARCINOMA

by

O BARTLEY, N EDLUND and C G HELANDER

Resection of the liver has been performed for many years in benign and malignant growths one important indication for surgery being primary carcinoma The resections in most of such instances have been confined to the left part of the liver According to a survey by PETTINARI (1960), about 40 resected cases with primary cancer have been published The method of massive resection of the right part of the liver has become well established in recent years and cases of primary cancer treated with this method have been published by QUATTLEBAUM (1962) PACK & ARIEL (1962) and others It may be mentioned that WENDEL (1911) was the first to excise the entire right part of the liver The patient had a primary carcinoma and survived the operation for nine years

Successful excision of a liver tumour requires careful mapping of the vascular anatomy of the liver beforehand in order to determine the extent of the lesion and if possible to establish its pathologic features

Earlier roentgenologic experience with hepatic tumours has largely been concerned with metastases In this connection splenoportography (GVOZDANOVIC et coll 1953 BERGSTRAND & EKMAN 1957 and STATTIN 1959) and arteriography (DOS SANTOS et coll 1929 BIERMAN et coll 1951 and ÖDMAN

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1958) have provided valuable information on the localization of the expansive processes.

BIERMAN et coll. have investigated three patients with hepatocellular and one with cholangiocellular carcinoma by means of arteriography. They reported 'irregular abnormal branching in unusual formation', 'diffuse, irregular Diodrast pooling' and 'decreased number and narrow vessels' in the former and 'practically no contrast medium in the liver' in the latter in which autopsy revealed 'almost complete infarction of the liver due to hepatic artery obstruction by tumour'.

MILANES et coll. (1953) described a primary malignant liver tumour with marked hypervascularization evident at arteriography. A search of the literature has revealed no systematic study of the angiographic appearances of primary liver carcinoma.

Angiography has proved a valuable tool in assessing tumours in other organs not only for the localization of expansive processes but also *in the* diagnosis of their pathology. The purpose of this report is to show that this is probably equally true in primary carcinoma. A preliminary report of the results was published by the present authors in 1962 and was verified in principle by BOIJSEN (1963).

Materials and Methods. The material consisted of 8 patients (6 women and 2 men), 50 or more years of age, treated in 1960 and 1961. All died and were examined post mortem. Histologic examination of specimens from the liver and certain other organs was carried out in every instance. Percutaneous liver biopsy had also been performed *in vivo* in four of the patients.

Angiography of the liver was performed in all the patients and splenoportography and cavography in one. Roentgen examinations of the stomach and colon, among other organs, had preceded angiography. Angiography was performed by percutaneous puncture of the femoral artery and catheterization with a radio-opaque catheter (Ödman No. 205). Aortography was performed in five of the patients with the tip of the catheter situated at the level of or slightly above the celiac artery. Selective angiography of the celiac artery was carried out in two patients and both methods were utilized in one. About 50 ml Urografin 60 % were injected with the aid of a Gidlund Elema pressure syringe for aortography and about 30 ml Urografin 60 % for selective angiography.

Splenoportography was performed after percutaneous puncture of the spleen and cavography after bilateral percutaneous puncture of the femoral vein and insertion of catheters so that their upper portions lay in the common iliac veins.

Results

Clinical data As regards symptomatology the reader is referred to a survey (EDLUND & LEANDOER 1966) in which the present material is included

Exploratory laparotomy was performed in five of the patients In four of these angiography preceded laparotomy and in the other it was performed after laparotomy because it could not be determined at the operation whether or not the left part of the liver was involved by tumour The planned resection could therefore not be accomplished without further roentgen investigations Tumours were demonstrated throughout the liver in these four patients In one of them a tumour the size of an orange was situated in the right part of the liver it lay below the hepatic surface and despite its size could therefore not be palpated during the operation

Considerable enlargement of the liver was noted at autopsy in every instance The weight of the liver varied between 3 and 8 kg A tumour lay in the right part of the liver in every patient in two of them it was solitary and in the other six patients multiple growths were dispersed throughout the liver In four of these six patients the largest masses were evident in the right part while in the remaining two the tumours were of approximately the same size in both parts of the liver Metastases were present in the lungs and in two patients there was local spread to involve the porta hepatis in one and the gallbladder in the other Only two patients were free from metastases or local spread one had a cholangiocellular and the other a hepatocellular carcinoma

Post mortem histologic examination disclosed that the liver tumours in 5 instances consisted of hepatocellular and in two of cholangiocellular carcinomas Hepatocellular as well as cholangiocellular structures were present in the remaining patient Cirrhosis of the portal type was observed in two patients

Histologic examination of the four specimens obtained at biopsy gave the correct diagnosis in one patient (cholangiocellular carcinoma) Malignancy which could not be further classified was evident in two patients and in the last patient only fatty degeneration was apparent

Roentgenologic findings The following changes were observed displacement of the intrahepatic arteries and veins presence of newly formed tumour vessels necrosis in the expansive process and displacement of adjacent organs, such as the aorta and the kidneys

Displacement of the intrahepatic vascular branches and tumour vessels occurred in all the patients investigated The vessels were arched and stretched around the expansive processes The newly formed vessels were fairly similar in appearance and in all instances except one occurred abundantly They were usually of relatively large caliber often with a diameter of 1 mm or more,

although smaller vessels also occurred They were regularly arranged, often in a clear cut radial formation Only fairly small luminal variations were usually observed in the newly formed vessels, these were characteristically filled with contrast medium quite early in the arterial phase and remained filled for a relatively long time Tumour veins were also slow to empty, often being filled for up to 20 sec after the start of the injection Arteriovenous shunts were often observed Large avascular areas were seen adjacent to the tumour vessels in three of the patients, these were considered to be due to necrosis in the tumour, a premise verified at autopsy (Figs 1 and 4)

Angiographic changes were evident in the right part of the liver in all patients, in 3 patients, changes were also observed in the left part

Caudal displacement of the right kidney occurred in 4 instances, in two of these left sided displacement of the aorta was evident at the hepatic level No definite displacement of the left kidney was apparent in the material

As has been mentioned, splenoportography and cavography were performed in one of the patients (large solitary tumour in the right part of the liver) Splenoportography revealed that the splenic vein had an abnormally vertical course because the porta hepatis was situated more medially than usual Only a very small vein leading to the right part of the liver was contrast filled The portal branch to the left part of the liver was well filled with medium and appeared normal No contrast defects such as might have indicated expansive processes occurred in the left part of the liver (Fig 2) Cavography disclosed a displacement of about 3 to 4 cm to the left and localized indentations of the lumen of the inferior vena cava at the hepatic level Lower down, the lumen was also markedly diminished due to partial thrombosis but not displaced Total obliteration of the left common iliac vein was evident, and because of thrombosis of this vein the medium stagnated in the small pelvic veins and then passed cranially via the widened ascending lumbar vertebral veins which are normally not contrast filled in this manner (Fig 3)

Discussion

Contrary to the results of BIERMAN et coll (1951), the angiographic appearances of the material were remarkably similar and characteristic In principle the same is true of the hepatocellular and cholangiocellular carcinomas with the exception, however, that the vascularity was less marked in the latter The one patient with sparse tumour vascularity had a cholangiocellular carcinoma Even if the angiographic appearances of primary liver carcinoma therefore seem to be typical, it cannot be concluded from the present limited material that this is really so Other tumours of marked vascularity may occur in the

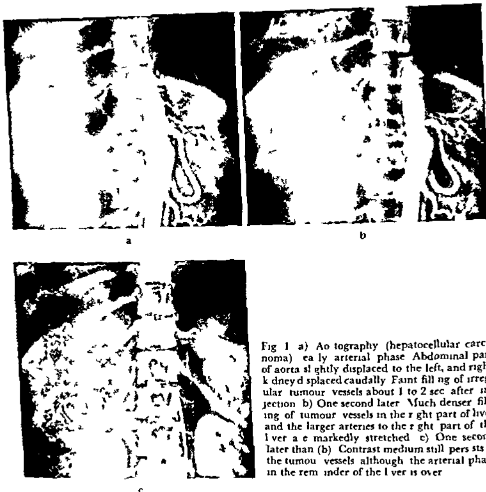


Fig 1 a) Aortography (hepatocellular carcinoma) early arterial phase Abdominal part of aorta slightly displaced to the left, and right kidney displaced caudally Faint filling of irregular tumour vessels about 1 to 2 sec after injection b) One second later Much denser filling of tumour vessels in the right part of liver and the larger arteries to the right part of the liver are markedly stretched c) One second later than (b) Contrast medium still persists in the tumour vessels although the arterial phase in the remainder of the liver is over

liver Malignant neoplasms are most commonly metastases and among the benign growths hemangioma is the most common and is usually cavernous Angiography of hepatic tumours including metastases, will be described in a subsequent report (BARTLEY HELANDER & STATTIN) and the possibility of a differential diagnosis between primary hepatic carcinoma and metastases will be discussed in detail It may be mentioned that metastases rich in vessels i e hypernephromas may occur although it seems possible to differentiate between the hepatocellular carcinomas and metastases due to the irregular vascular patterns in the latter On the other hand it may be difficult or impossible to differentiate between cholangiocellular carcinomas and metastases



Fig 2 Splenoportography (same case as in fig 1) The terminal part of the splenic vein pursues an abnormally vertical course *only a very thin vein supplies the right part of the liver* in which there is no accumulation of medium The branch of the portal vein to the left part of the liver appears normal with no decrease in the filling or displacement of the intrahepatic branches



Fig 3 Cavography (same case as in figs 1 and 2) The upper part of the vena cava is compressed and displaced some 3 to 4 cm to the right lobulated indentations are visible (←) the lumen is greatly diminished in the lower part The left common iliac vein is completely occluded

both may be poor in vessels and multiple The authors have to date had no experience with angiography of hepatic hemangiomas, these probably behave angiographically in the same manner as in e g the muscles (BARTLEY & WICKBOM 1959) and, if so, should certainly be distinguishable from primary hepatic carcinoma

The pathology of the hepatic lesion as well as its localization and extent are of great importance in the treatment As has already been stated tumours were angiographically demonstrated in the right part of the liver in each of the 8 patients In three of these, tumour vessels were also observed in the left part In the latter instances the angiographic and pathologic findings agreed, as they also did in two patients in whom the changes were demonstrated only in the right part of the liver Tumours, up to the size of a hazel nut, which had not been visible angiographically, were found at autopsy in the left part of the liver in the three patients just mentioned They died 1, 2 and 3 1/2 months, respectively, after the angiographic examination Whether or not these left sided



Fig 4 Aortography (hepatocellular carcinoma) The right kidney is displaced caudally the hepatic artery is considerably widened and the intra hepatic branches are stretched Extensive filling of tumour vessels in the early arterial phase (←) some areas within the tumour are unfilled due to necrosis (→→)

changes observed at autopsy existed at the time of angiography is not clear It is however possible that they actually were present but were too small to be seen

It is more difficult to demonstrate angiographic changes in the left than in the right part of the liver Some of the left part of the liver lies in front of the spine and at angiography the contrast filled spleen usually obscures part of the liver These difficulties could be diminished or overcome by supplementary examinations for example by angiography performed in different projections splenoportography and studies to assess the position of adjacent organs In the patient in whom splenoportography was carried out the examination was undoubtedly valuable in excluding changes in the left part of the liver

The right kidney was definitely displaced caudally due to enlargement of the adjacent portion of the liver in four of the patients In no instance however was any displacement of the left kidney observed It is possible on the other hand that left sided changes like those on the right side could give rise to caudal displacement of the kidney Observation of such displacements might help to confirm the presence of an expanding lesion of the left part of the liver

Hepatic angiography has in the present material been carried out either by aortography or selective celiac angiography Aortography revealed vessel displacements but no tumour vessels in the patient in whom both methods were utilized At the subsequent selective examination of the celiac artery however an abundance of tumour vessels was seen (Fig 5) In addition to the

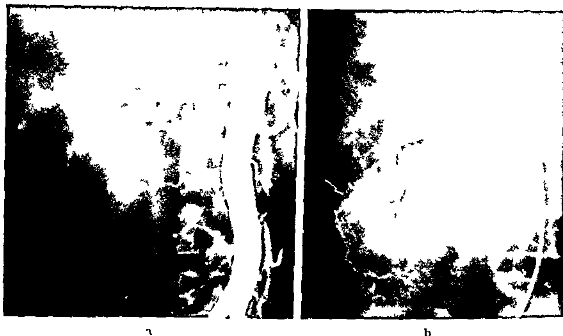


Fig 5 a) Aortography (hepatocellular carcinoma) Only a few irregular vessels are filled caudally in the right part of the liver b) Selective angiography of the celiac artery same arterial phase as in (a) Filling of numerous tumour vessels is now evident (←)

obviously better contrast filling of the tumour vessels a further advantage of the selective method is that only hepatic vessels are filled On the other hand, the method has certain disadvantages, it can be both difficult to carry out and time consuming Drawbacks in regard to aortography also exist, there is considerably less complete contrast filling of the tumour vessels and simultaneous filling of the other vessels in the area Aortography, however, has certain advantages It is easily and quickly performed and, concomitant with the investigation of the liver vessels, other organs, such as the kidneys, can be scrutinized for the possible presence of changes

Cavography may be of value for the surgical handling of patient with a hepatic growth This is illustrated to some extent in the patient of the present material in whom this investigation was performed It should be of value when the processes are located in the part of the liver that is adjacent to the inferior vena cava

The frequency of primary hepatic carcinoma among all other carcinomas is 1 2 % in Europe and 2 5 % in the United States (PACK & ARIEL 1962) In Sweden it is recorded as being 0 6 % of all carcinomas and about 10 % of carcinomas localized to the liver, pancreas and biliary system Of the two forms, hepatocellular and cholangiocellular carcinoma, the former is 3 to 4 times more common than the latter

Primary hepatic carcinoma is thus rather rare although attention must be directed towards the disease in clinically suspected malignancy The symptomatology in patients with primary hepatic carcinoma is generally so varied that the diagnosis is difficult to confirm (ROSENBERG & OCHSNER 1948 and MACDONALD 1957), as in malignant disease in other situations Of the investigations that thave been employed for diagnosis of primary hepatic carcinoma angiography is probably the most promising The present results indicate that neither liver biopsy in vivo nor the exploratory laparatomy proved to be wholly satisfactory from the diagnostic point of view Proper selection of subjects to have liver angiography performed is however, necessary The clinical findings that primarily direct attention towards the presence of a hepatic growth are hepatomegaly and isolated elevation of the serum alkaline phosphatase (EDLUND & LEANDOER) The possibility of hepatic malignancy in patients with such an isolated serum abnormality has been pointed out by GUTMAN et coll (1940) GIBBONS 1957 GREENE & SCHIFF (1961) EDLUND & KEWENTER (1962) and others

SUMMARY

The angiographic appearances in 8 patients with primary hepatic carcinoma are described Abundant typical tumour vessels were evident in all instances although these cannot as yet be considered pathognomonic of the condition

ZUSAMMENFASSUNG

Die angiographischen Erscheinungen von 8 Fallen von primarem Karzinom der Leber werden beschrieben Alle Falle zeigten reichliche und karzinomtypische Gefassneubildungen trotzdem können diese noch nicht als pathognomonisch betrachtet werden

RÉSUMÉ

Description des signes angiographiques chez 8 malades atteints de cancer primitif du foie Il y avait dans tous les cas de nombreux vaisseaux tumoraux typiques bien qu on ne puisse encore less considérer comme pathognomoniques de cette affection

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FROM THE RADIATION APPARATUS DIVISION (DIRECTOR TAKAHASHI NAKAHORI), SHIMADSU SEISAKUSHO LTD KYOTO JAPAN

ADVANTAGES OF THREE PHASE ROENTGEN UNITS

by

HITOSHI KANAMORI

It is generally considered that roentgenograms obtained with three phase units are of better quality than those produced with single phase units, this is attributed to increased sharpness since three phase units demand a shorter exposure time (BERG et coll 1962 WATSON et coll 1962 KANAMORI 1966 a) Also by reason of the inherent properties of roentgen tubes the optimal exposure factors can easily be determined with a three phase unit this advantage will be dealt with in the present communication

Applied kilovoltage as a function of primary voltage and milliamperage The voltage current characteristics of a typical roentgen tube coupled to a single phase unit are shown in Fig 1 The milliamperages (average currents) are indicated by the curves the terminal points on the abscissa recording the kilovoltages The tube current is usually saturated but the degree of saturation decreases and approaches a straight line when the kilovoltage is low and the milliamperage is high as with the curve of 40 kV and 400 mA

The corresponding current and voltage waveforms at 40 kV and 60 kV are given in Fig 2 With 40 kV and 400 mA (unsaturated case) the current

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The corresponding current and voltage waveforms at 40 kV and 60 kV are given in Fig 2 With 40 kV and 400 mA (unsaturated case) the current

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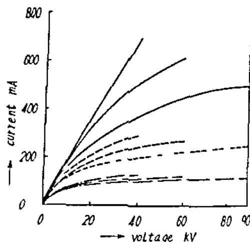


Fig 1 Voltage/current characteristic curves of a roentgen tube used with a single phase unit Average currents of curves are 400 mA (full lines) 200 mA (dash lines) and 100 mA (dot and dash lines) With low kilovoltage and high milliamperage the current is not saturated so that the ratio of peak current to average current is high compared with the saturated case

waveform is steep at the top and forms a triangle similar to that of the voltage waveform The current saturation increases as the milliamperage decreases or the kilovoltage increases, so that the current waveforms become flatter at the top than the voltage waveforms The areas under the current waveforms in Fig 2 were made identical for each kilovoltage, and the ratios of the peak currents to the average currents may therefore be compared by measuring the heights of the peaks The ratio is higher in unsaturated than in saturated cases, for example, with 40 kV and 100 mA (unsaturated case) the ratio is 1 73, while with 10 kV and 100 mA (saturated case) the ratio is 1 30

The voltage current characteristic curves of a tube coupled to a three phase unit vary within a small range, since the voltage pulsations are less than with a single phase unit The ratios of peak current to average current will therefore be almost constant regardless of the degree of saturation, for example, with 60 kV and 700 mA (unsaturated case) the ratio is 1 04, while with 60 kV and 100 mA (saturated case) the ratio is 1 03

A chart from a single phase unit for obtaining applied kilovoltages from the primary voltages of a high voltage transformer and from milliamperages is presented in Fig 3 The abscissa indicates the primary voltage before the tube current is supplied i e under no load The line of zero milliamperage may be obtained from the equation

$$\text{kilovoltage} = \sqrt{2}\, n \ \text{primary voltage}/1000$$

where n is the turn ratio of secondary to primary windings of a transformer When current flows, the decrease in kilovoltage from the no load value equals the voltage drop within the unit Since the voltage drop at peak value is almost proportional to the peak current, if the ratio of peak current to average current

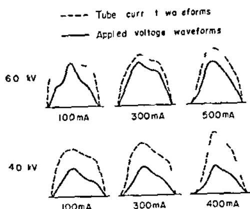


Fig 2 Applied voltage waveforms and current waveforms of a single phase unit at low kilovoltages At a high m A the current does not become saturated when the voltage decreases (compare fig 1) the current waveform is therefore rather sharply pointed at the top and the ratio of peak current to average current is large compared with other cases

is kept constant the isomilliamperage curves become almost parallel and have equal intervals for the same milliampere differences With a single phase unit however, as stated above the voltage drop per milliampere becomes greater with higher milliamperages and low kilovoltages and the curves will be open at the bottom as shown in Fig 3

Fig 4 depicts a kilovoltage chart of a typical three phase unit in which the same tube was used as in the preceding experiment with a single phase unit The curves are almost parallel and have equal intervals for the same milliampere differences

With low kilovoltage and high milliamperage an equal percentual variation in primary voltage produces larger deviation in kilovoltage with a single phase unit than with a three phase unit This is because the gradients of the curves are steeper in the lower half of Fig 3 than those in Fig 4 provided that the gradients of the zero milliamperage line of both figures are identical

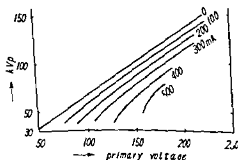


Fig 3 Chart of a single phase unit for obtaining kilovoltage from the primary voltage and milliamperage This set of isomilliamperage curves are open at the bottom due to the inherent properties of roentgen tubes

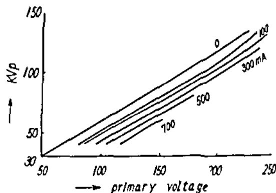


Fig 4 Chart of a three phase unit for obtaining kilovoltage from the primary voltage and milliamperage The isomilliamperage curves do not open at the bottom since the ratios of peak current to average current are almost equal whether or not there is tube current saturation

Equal percentage variations in the filament voltage of a roentgen tube produce equal percentage deviations in milliamperages Therefore, again with a low kilovoltage and high milliamperage, an equal percentage variation in the filament voltage produces greater kilovoltage deviation with the single phase than with the three phase unit This is because the intervals between the curves in the lower half of Fig 3 are larger than between those in Fig 4, even if the voltage drop per milliampere in the two units is identical (provided they have the same zero milliamperage line gradient)

Kilovoltage variations in both instances are therefore larger with single phase than with three phase units Because the exposure factors of high milliamperage and low kilovoltage have long been used in low kilovoltage roentgenography, the above properties are of the utmost importance in discussing roentgenographic effects

Variations in optimal roentgenograms due to the deviation in exposure factors New definitions of optimal roentgenograms and exposure factors, as well as a method for representing the roentgenographic effect, were given in a previous paper (KANAMORI 1966a) The method consists in making the rectangle, the abscissa of which is the object thickness range under examination, and the ordinate is the optimal logarithmic exposure range of film emulsion, correspond to the optimal density range (KANAMORI 1966b) If the composition of the object changes, an equivalent thickness range, reduced to one material, must be used A curve that passes through the two corners of the rectangle must now be found from the set of thickness to logarithmic screen brightness (log E) curves The exposure factors, i e kilovoltage, mAs, and focus film distance (FFD), corresponding to the curve thus selected, are optimal, since contrast due to change in object thickness is maximal for the entire thickness range The rectangle and the optimal curve are shown with diagonal lines (full lines) in Fig 5 If the exposure factors are not optimal, the thickness to

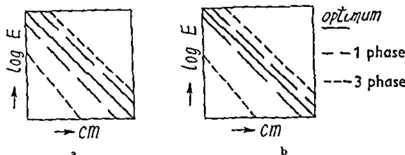


Fig 5 Deviation from the optimal roentgenogram of 3 33 cm to 10 cm acrylite phantom with 1 8 m FFD under respectively ± 5 deviation in primary voltage (a) and ± 2 deviation in filament voltage (b) The deviations with a single phase unit are larger than with a three phase unit in both instances so that the optimum exposure factors may be more easily determined with the latter than with the former

exposure curves deviate from the optimal curves The degree of roentgenographic deviation can therefore be easily observed with these figures

The data with the same unit as was used in the previous investigation (KANAMORI 1966) may be taken for examplifying The optimum exposure factors of 3 33 to 10 cm acrylite with a 1 8 m FFD with a single phase and a three phase unit were obtained as shown in the third column of the Table The fourth and fifth columns are the deviated exposure factors due to ± 5 % deviation in primary voltage and ± 2 % deviation in filament voltage respectively The deviations in kilovoltage with the single phase unit are larger than with the three phase unit due to the factors discussed earlier With these deviations the roentgenographic effects differ from the optimal as shown by the broken lines in Fig 5 In this figure, (a) and (b) correspond respectively to primary voltage and filament voltage deviations The roentgenographic

Table

Variations in kilovoltage and milliamperage when the primary voltage or filament voltage deviates from its optimal value

Exposure factors	Type of units	Optimal values	Values with the deviation of ± 5 in PV	± 2 in FV
kV	3φ	55	51 59	53 57
	1φ	60	46 70	45 68
mA	3φ	600	600	540 660
	1φ	500	500	450 550

variations with a single phase unit are greater than with a three phase unit in both instances, and is particularly evident with negative deviations It may therefore be concluded that optimal exposure factors can be determined more easily in low kilovoltage roentgenography with a three phase unit than with a single phase unit

Moreover, with low kilovoltage and large milliamperage from a single phase unit, the exposure due to rays transmitted through an object increases with the milliamperage, even at the same kilovoltage and a constant mAs product With a three phase unit the change in exposure is negligible (KANAMORI 1966a) This is because the exposure per milliampere second is proportional to the ratio of peak current to average current (milliamperage) at such a low kilovoltage as 40 kV Only the hardest rays, with radiation at voltage peak (simultaneous with the current peak), can pass through a primary filter and an object when such a low kilovoltage is used Since the exposure factors are usually expressed in kV and mAs, the change in exposure per mAs with increase in milliamperage causes additional difficulty in determining the optimal factors when a single phase unit is used

SUMMARY

The optimal exposure factors in low kilovoltage roentgenography with three phase and single phase units are considered It is shown that these may be determined more easily with the former than with the latter the reason is explained

ZUSAMMENFASSUNG

Die optimalen Belichtungsfaktoren für Niedrigspannungsaufnahmen wurden am 3 Phasen apparat und am 1 Phasenapparat festgestellt Dies konnte leichter am 3 Phasenapparat vorgenommen werden als am 1 Phasenapparat Die Gründe hierfür werden angegeben

RÉSUMÉ

L auteur étudie les facteurs d exposition optimaux pour la radiographie à bas kilovoltage avec des appareils triphasés et monophasés Il montre qu il est plus facile de les déterminer en triphasé qu en monophasé et en explique la raison

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RADIOLOGIC DIAGNOSIS OF CECAL TUMOURS

by

STIG OLSSON

Special problems arise in the radiologic examination of the cecum, one of which is due to the fact that it is generally much wider and more mobile than the rest of the large bowel Thus a small lesion of the wall may vary in position being situated medially or at other times laterally even in the same examination series Furthermore due to the width of the cecum, small lesions may easily be obscured by the high density of the contrast medium at barium enema examinations This source of error may be eliminated by the double contrast method but it is then frequently difficult to obtain a continuous and non segmented mucosal coating Adequate cleansing of the proximal part of the colon is seldom attained Fecal material in the distal part of the colon is often transported along with the cleansing enema to the proximal part where it remains The double contrast method in particular makes it advisable to use a tilting table so that the upper part of the body can be lowered with the patient supine or lateral Minor tumours in the cecum may be difficult to recognize because they are rather often more flat than those in other parts of the colon and consequently are only slightly raised from the mucosal wall

Polypoid filling defects often occur at the ileocecal valve or at the junction of the appendix and the fundus of the cecum The ileocecal valve is often visible

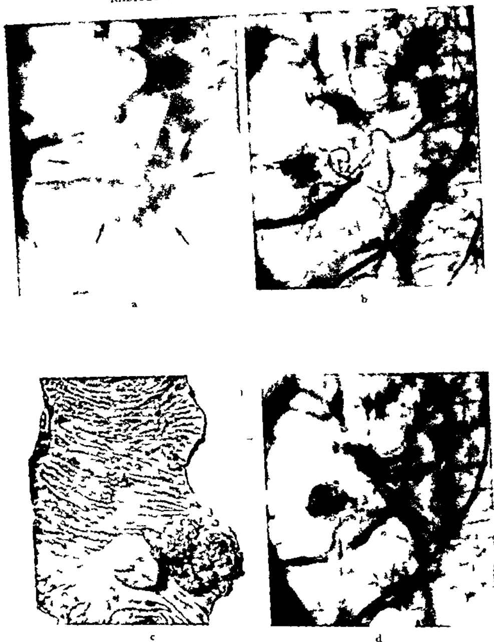
From Roentgen Department II (Director Docent I Wickbom) Sahlgrenska Sjukhuset Gothenburg Sweden Submitted for publication 29 March 1965



Fig. 1. a) Lipohyperplasia of the valve. Another defect above the valve proved to be a lipoma (arrow). b) Two rounded defects at the level of the valve due to lipohyperplasia.

on examination of the colon as a more or less rounded filling defect, although on rotation of the cecum it is not always situated medially but may lie on the dorsal or even lateral wall. The double contrast method often makes it possible to discern the upper and lower lips with the slit like lumen of the valve between them. If the barium contrast medium does not pass into the terminal ileum from below it may be necessary to complete the series with an examination of the small intestine in order to note the exact relation between the entrance of the ileum into the colon and the filling defect.

The size and shape of the ileocecal valve may vary considerably, and may sometimes readily be mistaken for a tumour. An enlarged valve may possibly be due to ileocecal intussusception but more likely to an excessive accumulation of fatty tissue (Fig. 1). As ZETTERGREN (1953) pointed out, the occurrence of excessive amounts of fatty tissue in the valve is very common, especially in general abdominal adiposity. The fatty tissue does not have the character of a lipoma but may be described as lipohyperplasia. Selective angiography of the superior mesenteric artery by the method introduced by ÖDMAN (1959)



a b c d

F g 2 Ade ocarc ma near the valve l pohyperplasia of the upper l p a) Barium enema Prom nent d fect at the le l of the valve (arrows) b) Angiography Irregular and tortuous vessels at the upper pa t of the def ct (arrow) c) Operat on spec men d) Early fill ng of wide drainage v n (rrow)



Fig. 3. Two cases of inversion of the appendiceal stump. a) In addition a plump valve with a longitudinal slit between the lips. b) This case has been observed for more than a year but has not been operated.

may be of considerable value in uncertain cases, in the differential diagnosis between carcinoma and lipohyperplasia of the valve (Fig. 2).

Lesions sometimes appear as more or less rounded filling defects at the fundus of the cecum. These defects are often dependent on prolapse of an inverted appendiceal stump and may be polypoid with a lobulated contour or have a kidney shaped appearance (Fig. 3). They may remain for several years after operation, indeed inversion of the appendiceal stump may be impossible to distinguish from a tumour (Fig. 4), and it is advisable not to be satisfied with the explanation that the appendix has been removed. A filling defect at the fundus of the cecum may also be dependent on true appendico-colic intussusception, as described by SKARBY (1941). This may occur temporarily and probably only then cause clinical symptoms (Fig. 5). Deformity at the fundus due to edema and induration, secondary to inflammatory disease of the appendix, has been described by FIGIEL & FIGIEL (1962).

An inflammatory condition may also produce changes in the cecal wall, evident as more or less irregular thickening of the wall and difficult to distinguish

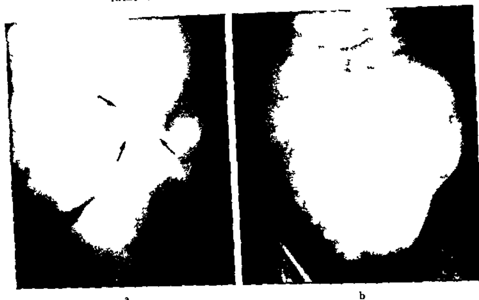


Fig 4 a) Defect due to papilloma with atypical epithelium and above an enlarged valve (arrows)
b) Prominent defect due to inversion of the appendiceal stump

from carcinoma Selective angiography of the superior mesenteric artery may be of diagnostic value in these cases With selective angiography of the inferior mesenteric artery STRÖM & WINBERG (1962) demonstrated rapid filling of veins from a pathologically changed part of the sigmoid colon in most of the cases in which an adenocarcinoma was subsequently found On the other hand no early filling of the veins could be demonstrated in any of the cases of histologically verified inflammatory conditions of the sigmoid colon Further examinations have corroborated this observation It is true that the experience of the author with angiography of the superior mesenteric artery is limited but comparatively rapid filling of the drainage veins in the proximal part of the colon has been demonstrated in the tumour cases

A 5 year material was examined in detail in order to estimate the reliability of the radiologic diagnosis of lesions of the cecum Cases with radiologic changes more or less typical of tumour were selected and the diagnosis was compared with the operative findings in each Furthermore the case histories of all cases with a pathologically verified diagnosis of carcinoma of the proximal part of the colon which had been subjected to operation during the same period of time were examined to determine what proportion had been correctly diagnosed radiologically



Fig. 3. Two cases of inversion of the appendiceal stump. a) In addition, a plump valve with a longitudinal slit between the lips. b) This case has been observed for more than a year but has not been operated.

may be of considerable value in uncertain cases, in the differential diagnosis between carcinoma and lipohyperplasia of the valve (Fig. 2).

Lesions sometimes appear as more or less rounded filling defects at the fundus of the cecum. These defects are often dependent on prolapse of an inverted appendiceal stump and may be polypoid with a lobulated contour or have a kidney shaped appearance (Fig. 3). They may remain for several years after operation, indeed inversion of the appendiceal stump may be impossible to distinguish from a tumour (Fig. 4), and it is advisable not to be satisfied with the explanation that the appendix has been removed. A filling defect at the fundus of the cecum may also be dependent on true appendico-colic intussusception, as described by SKARBY (1941). This may occur temporarily and probably only then cause clinical symptoms (Fig. 5). Deformity at the fundus due to edema and induration secondary to inflammatory disease of the appendix, has been described by FIGIEL & FIGIEL (1962).

An inflammatory condition may also produce changes in the cecal wall, evident as more or less irregular thickening of the wall and difficult to distinguish

positive diagnosis was impossible In the remaining two cases superficial adenocarcinomas about 3 cm in diameter were present at the level of the valve No definite malignant lesion could be observed however, on reviewing the films The examination was made by the double contrast method in both of the cases and was considered technically satisfactory

The radiologic examination of the cecal region may thus present special problems It is often necessary to repeat the barium enema examination as well as to employ the double contrast method Superficial tumours of the ventral and dorsal wall of the cecum are particularly liable to be missed in spite of an adequate examination technique A plump ileocecal valve may be mistaken for a tumour The author has found selective angiography via the superior mesenteric artery to be of considerable value in such cases this examination may also be of value in the differential diagnosis between carcinoma and an inflammatory condition

Cases of persistent intestinal bleeding or symptoms of malignant disease unexplained by radiologic examinations should be reconsidered and if nothing more the films should be re examined with particular attention to the cecal region

SUMMARY

The radiologic examination of the cecum for malignancy is discussed with reference to a 5-year material of 55 cases Tumours at the ileocecal valve and the fundus of the cecum are particularly considered and the value of selective angiography of the superior mesenteric artery in uncertain cases is emphasized

ZUSAMMENFASSUNG

Die Rontgendiagnose des Karzinoms des Zokums wurde an einem funfjahrigen Material von 55 Fallen kritisch uberpruft Besondere Beachtung fanden die Tumoren der Ileozokalklappe und jene am Boden des Zokums Der Wert der selektiven Angiographie der oberen Mesenterialarterie fur die Abklarung unklarer Falle wird betont

RÉSUMÉ

L auteur etudie l examen radiologique des tumeurs malignes du caecum d après une série de 55 cas en 5 ans Il étudie en particulier les tumeurs de la valvule iléo-caecale et du bas fond caecal et souligne l intérêt de l angiographie sélective de l artère mésentérique supérieure dans les cas douteux



Fig. 5. *Defect at the base of cecum.* (The patient had pain in the right iliac fossa; on operation one month later the cecum and appendix were normal. The symptoms were probably due to temporary appendico-colic intussusception.)

Fifty-five cases had probable tumour changes in the cecum and adjacent portion of the ascending colon, demonstrated radiologically by barium enema examination during the 5-year period (1959 to 1963). Forty-six of these were subjected to operation, two of the remaining nine having refused radical treatment. Lipohyperplasia of the valve or prolapse of an inverted appendiceal stump was considered fairly certain in seven of these cases. The nine cases have been observed for at least a year after the examination, and none has been admitted to hospital during the observation time.

Malignant tumours of the cecum and adjacent portion of the ascending colon were present in 4 cases at operation or autopsy during the same 5-year period and had not been diagnosed previously by contrast examination of the colon. A review of the films of these four cases revealed that in one case a malignant lesion at the proximal part of the ascending colon had been overlooked at two examinations; on the other hand, numerous diverticula of the sigmoid colon had been diagnosed, which may at least partially explain why the diagnosis of a growth was not made preoperatively. In another case the barium enema examination was performed as an emergency without any preparation and considerable fecal material obscured the region so that a

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KINKING OF THE INTERNAL CAROTID ARTERY

A roentgenologic and histologic study

by

KERSTIN BOSTROM and TORGNY GREITZ

Kinking of the internal carotid artery is frequently demonstrated at angiography AZAMBUJA et coll (1963) found kinking in 67 of 320 patients and WEIBEL & FIELDS (1965) in 53 out of 1 046 patients According to the latter kinking is an angulation of one or more segments of the internal carotid artery associated with stenosis in the affected segment At angiographic examinations in older patients the present authors have frequently observed kinking not only in the internal carotid artery but also in the vertebral arteries and occasionally in the femoral artery (Figs 1 to 4) A small fold like protrusion bulges into the lumen at a sharp bend of the vessel this fold is well demarcated when seen in profile and has a width of a few millimetres It is evident in the frontal projections as a narrow streak of decreased density (Figs 1b 2a) Kinking is thus always associated with tortuosity of the vessel involved Angiographic evidence of impaired circulation at the level of the stenosis has occasionally been present (Fig 2)

The literature suggests some uncertainty regarding the nature of the

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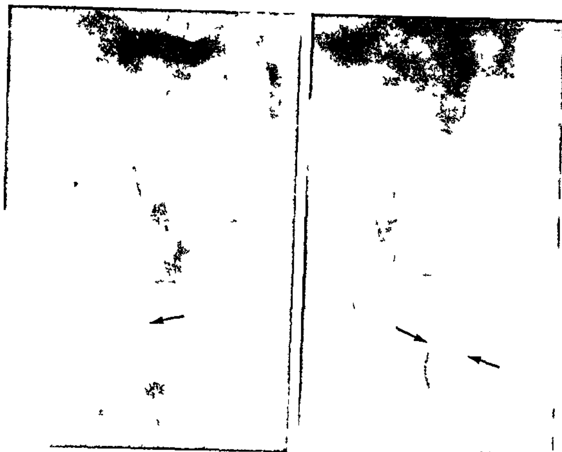


Fig 1 From the clinical material Angiography of the right internal carotid artery Typical kinking of the artery a thin fold protrudes into the lumen at the concave aspect of the bend as evident in the a p view in the lateral view it appears as a streak of decreased density

stenosis A simple mechanical process (WEIBEL & FIELDS) appears to be the most widely accepted explanation of its origin, a similar fold can be created by bending a rubber tube (Fig 5) Whether the folding is associated with a diffuse or local change in the vessel wall does not appear to have been established (WEIBEL & FIELDS) It is known that intimal proliferation may occur at locations where flow conditions in a vessel are locally changed primarily adjacent to a bifurcation (HASSLER 1961) Theoretically, an intima reaction could be due to circulatory disturbances secondary to tortuosity or coiling of the artery (BAUER et coll 1961) Finally, the question of whether kinking is congenital or acquired has not been settled (WEIBEL & FIELDS) no clear description of the radiologic appearances of kinking seems to have been published The angiographically demonstrated stenosis has, in certain instances, been verified macroscopically at operation but has not been established by microscopic examination In order to elucidate the histologic nature of the changes asso

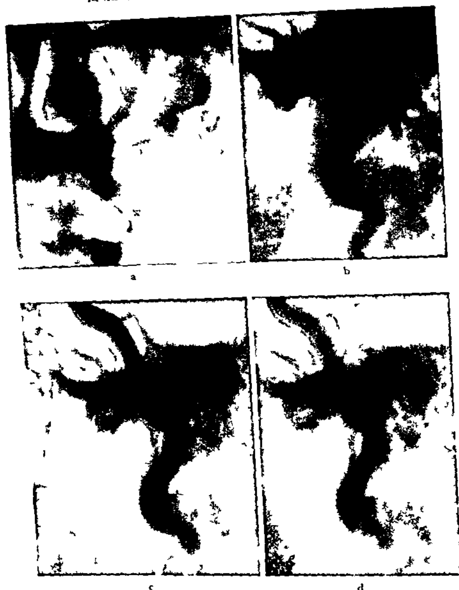


Fig. 2. Same case as in fig. 1. Angiography of the left internal carotid artery. On this side post-stenotic dilatation [illegible] apparent containing a central filling defect which appears early in the series (a, b, [illegible]) successively replaced by a peripheral filling defect (d).



Fig. 3. From the clinical material. a) Aortocervical angiography. Kinking of the left vertebral artery at two levels. b) Femoral arteriography. Kinking of the popliteal artery.

ciated with kinking, the present authors have therefore undertaken a combined roentgenologic and pathologic study on an autopsy material.

Material and Methods. Unilateral angiography of the internal carotid artery has been performed post mortem in 30 subjects of more than 50 years of age. Mixobar*, suspended in three parts of a 5 % gelatin solution, was used as contrast medium. The external carotid artery and the intracranial portion of the internal carotid artery above the posterior communicating artery were ligated. The contrast material was injected into the common carotid artery in sufficient quantity to fill the internal carotid artery. A roentgen examination was made with the vessel in situ, usually in the anteroposterior and lateral projections so as to overcome coiling or tortuosity.

Kinking of the internal carotid artery was demonstrated in two women of age 73 and 75, respectively; slight general atherosclerosis was present in both.

The artery with its surrounding tissue was removed and fixed in 10 % formalin, after which the vessel was cleansed of adjacent tissue, and further roentgen examination was performed. The segments with kinking were selected for histologic examination and, in addition, several specimens were embedded in paraffin and cut in longitudinal and transverse sections. The sections were stained with PAS, toluidine blue, and according to Gomori (1950), and van Gieson.

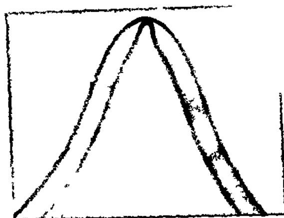


Fig 4 Kinking of a rubber tube examined radiologically the wall of the tubing has increased in thickness within the fold

Results

Roentgenologic examination The appearances of the stenosis at angiography post mortem was the same as seen in living subjects A small fold like indentation about 1 mm wide and a few millimetres high, located at the concave side of the lumen and corresponding to the top of the bend was present in the tortuous artery Two stenosing folds one located close to the skull base the other a few centimetres caudally were evident in one of the cases Since the vessel curved mainly in the frontal plane the folds were seen in the anteroposterior projection (Fig 6) In the second case the stenosis was located midway between the bifurcation and the base of the skull, and was shown best in the lateral projection (Fig 7)

Microscopic examination The microscopic appearances were the same in both cases With the exception of the stenotic fold the vessel wall was thin with degenerative changes localized to the media (Fig 9) The elastic tissue and smooth muscle were destroyed and the ground substance was increased Local vacuolation of the stroma and increase in the metachromatic material was observed There were no intimal changes The stenosis was caused by folding of the entire wall of the artery and was consequently made up of all its layers Fig 8) The vessel wall was thickened at the folding because of an increase in the collagen fibres of the media There were no signs of inflammatory disease

Discussion

Most authors have regarded kinking of the internal carotid artery as an



Fig 5 From the autopsy material Typical kinking of the internal carotid artery at two levels Roentgen examination in situ (a) and of the dissected vessel (b)

It has been considered a result of arteriosclerosis, with destruction of elastic tissue (QUATTLEBAUM et coll 1959, BAUER et coll), which causes elongation of the artery This in turn brings about a folding of the vessel wall since the artery is fixed at both ends The present results favour this theory



Fig 6 From the autopsy material a) Typical kinking of the internal carotid artery b) Roentgen examination of the dissected vessel

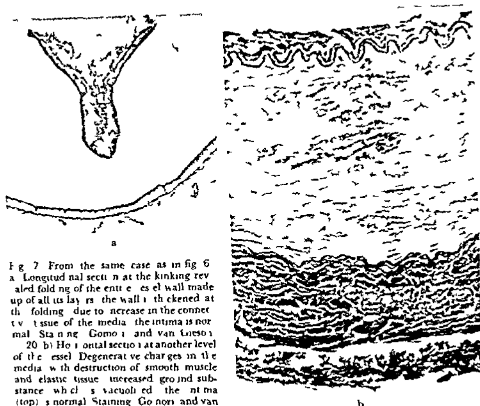


Fig 7 From the same case as in fig 6 a Longitudinal section at the kinking revealed folding of the entire vessel wall made up of all its layers the wall is thickened at the folding due to increase in the connective tissue of the media the intima is normal Staining Gomori and van Gieson × 20 b) Horizontal section at another level of the vessel Degenerative changes in the media with destruction of smooth muscle and elastic tissue increased ground substance which is vacuolized the intima (top) is normal Staining Gomori and van Gieson × 256

FLORIN (1965) claimed that local changes were present at the site of kinking No information was however given about the nature of this change The degenerative changes located to the media and occurring in the present cases can be ascribed to the ageing process involving elastic tissue as well as smooth muscle and ground substance (BOYD 1961) The fibrosis of the media, which was observed at the fold may have been due to nutritional disorders secondary to mechanical strain on the vessel wall As has been pointed out before the fold may predispose to damage of the intima and thrombosis (BAUER et coll) No intima changes could be demonstrated within the folds

SUMMARY

Kinking of the internal carotid artery has been studied roentgenologically and histologically Kinking may be defined as an in folding of the concave aspect of a tortuous artery resulting in stenosis The investigation favours the theory that the folding has a mechanical basis and occurs in arteries that have been elongated by degenerative changes within the media

ZUSAMMENFASSUNG

Abknickungen der Arteria carotis wurden röntgenologisch und histologisch untersucht. Eine Abknickung kann als eine Falte auf der konkaven Seite einer geschlängelten Arterie definiert werden. Die Untersuchung weist darauf hin, dass die Faltung aus mechanischen Gründen entsteht, wenn die Arterien sich durch Degeneration der Media verlängern.

RÉSUMÉ

Les auteurs ont étudié radiologiquement et histologiquement les coudures de l'artère carotide interne. La coudure peut être définie comme une plicature de la concavité d'une artère tortueuse donnant lieu à une sténose. Ce travail vient à l'appui de l'hypothèse que cette plicature est due à un facteur mécanique et apparaît dans des artères qui sont allongées par lésions dégénératives de la média.

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CAPILLARY PHASE IN CEREBRAL ANGIOGRAPHY

by

BENGT LILIEQUIST

MONIZ who introduced carotid angiography in 1927, described an arterial phase an early venous phase and a late venous phase He also claimed that a capillary phase could be identified in roentgen films exposed a second after injection of the contrast medium provided the amount did not exceed 10 ml The classification of the cerebral circulation introduced by MONIZ has gradually changed to comprise arterial capillary and venous phases

With the introduction of rapid serial angiography new possibilities were offered for further studies of the cerebral circulation, and it soon became obvious that the old concepts were not always valid A true capillary phase was not always evident in serial angiographies as the veins began to fill with contrast medium immediately after the arteries were empty WICKBOM (1948) stated that small veins were filled before the arteries had emptied SCHURR & WICKBOM (1952) employing rapid serial angiography noticed in 9 out of 21 normal cases a phase in which no medium in either arteries or veins was evident thus confirming the existence of a true capillary phase On the other hand JOHANSSON (1954) in an investigation of 30 cases with rapid serial angiography was unable to confirm the existence of a capillary phase

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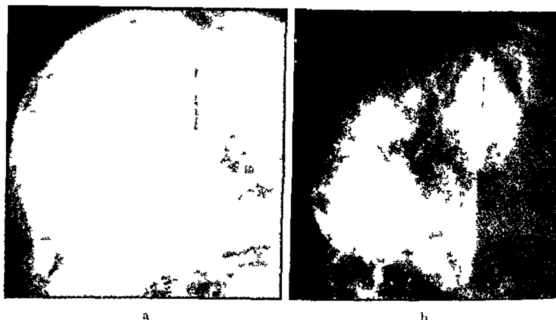


Fig. 1. A.p. views with subtraction. a) Capillary phase. b) The midline cortical structures are visible also on the contralateral side.

GREITZ (1956) was the first to explain the concepts of arterial and venous phases in rapid serial angiography. He distinguished between an arterial filling and an arterial emptying phase as well as a venous filling and a venous emptying phase. This author also pointed out that the longer the injection time, and the larger the amount of medium, the less are the chances of obtaining a true capillary phase.

The capillary phase has mainly been regarded as a phase transitional between the arterial and the venous phases and of no real practical significance. It has also been suggested that the concept 'capillary phase' should be abolished and replaced by an arteriovenous or transitional phase. In modern textbooks, it has either been completely omitted or only touched upon (LINDGREN, TAVERAS et coll., DILENGE, BONNAL & LEGRE, DECKER, TÖNNIS & SCHIEFER, KAUTZKY & ZÜLCH).

The appearance of the capillary phase in roentgen films has been alluded to as a diffuse 'staining' of the cerebrum, apparent mainly in the a.p. views though also distinguishable in lateral views. It is stated (DILENGE, KAUTZKY & ZÜLCH, TAVERAS & WOOD, BONNAL & LEGRE, TÖNNIS & SCHIEFER, LIMA) to appear as a homogenous 'staining' containing no recognizable structures, the only exception being that the concomitant appearance of small arteries or veins are said to be observable. It is generally assumed that this phase is of



Fig 2 A p view s a) The pericallosal artery is *not filled and the* corresponding cortical structures not outlined b) Vertebral angography Close to the midline there is bilateral staining of a wide area

no real practical importance as it is inconstant and not well defined (TAVERAS & WOOD)

Careful anatomical and histological investigations of the vascularization of the cerebral structures mainly date back to the work *of* DURET (1872) This author distinguished between two kinds of *arteries namely long* cortical or medullary arteries that end in the medullary substance, and short or cortical arteries terminating in the *cerebral cortex* the two varieties forming a capillary network This network is continuous throughout the brain substance, as has been shown by PFEIFFER Other investigators have added further informations to our knowledge of the distribution *of the smaller* arteries and veins in the cerebrum It has been shown that the cortical substance as well as the basal ganglia of the cerebrum *are supplied* with a very rich and dense capillary network In fact the number *of capillaries in* the cortex far exceed those in the medullary substance According *to* SCHNEIDER the relation between the number of capillaries in the cortex and the white substance amounts to between 3 1 and 6 1 The possibility thus exists for larger amounts of contrast medium to be found in the cortex *than in* the white substance during cerebral angiography It should therefore *also* be possible to distinguish the cerebral cortex from the medullary substance *in* roentgen films that have been exposed during the interval that contrast medium is present in the capillaries of the



Fig. 3. Half axial view. The lateral ventricles, mainly the lateral wall of the cella media, are well shown.

brain. The identification of the small contrast differences in the roentgen films demands the employment of the subtraction method (ZIEDSES DES PLANTES 1961, 1963).

Method. Rapid serial angiography is employed as standard for all patients undergoing cerebral angiography in our department. The investigation includes two films per second in the first five seconds for lateral as well as a.p. views. The exposures cover a total period of 15 seconds, the interval between the exposures after the first five seconds being longer.

As the amount of contrast medium used is small (4 to 6 ml) it is necessary that the whole or at least most of it should pass into the internal carotid artery in order to achieve an optimal capillary phase. The internal carotid artery is punctured with a short bevelled needle. If the puncture is performed in the main direction of the vessel, and care is taken not to perforate the posterior wall of the vessel, the needle, left to itself, will proceed further into the lumen of the vessel without unnecessary damage to the wall. This will ensure

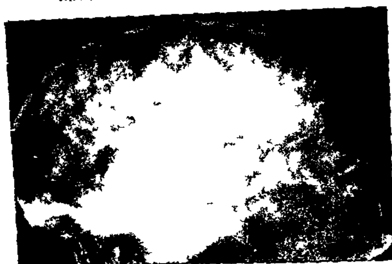


Fig 4 Capillary phase ch acterized by a wavy appearance of the cort cal st uctu es

the best position for the needle and also allow an examination with small risks of secondary haemorrhage after the needle has been withdrawn

Although the capillary phase appears most distinctly when the medium is *introduced* into the internal carotid artery an injection into the common carotid artery will also give rise to a useful capillary phase If *the common* carotid artery has to be punctured however, this should be done low *down in the neck* The *least* suitable site is immediately proximal *to the bifurcation* of the common carotid artery since in that position the tip of the needle may swing aside during the injection so *that most* of the contrast medium enters the external carotid artery

The injection is given with an automatic injection pump permitting of the introduction of 4 *to* 6 *ml contrast* medium during 1 to 1 5 seconds The amount of medium has been standardized *to* 4 *to* 6 *ml* Urografin 60 % for each injection the larger amount *being used for* a p as well as for lateral views when the common carotid artery is punctured *Vertebral* angiography is performed mainly percutaneously and the medium is injected by hand A catheter introduced by the Lindgren method *is used in selected* cases

The subtraction method has *been applied* routinely in all carotid and vertebral angiographies and has been *rendered* possible by a simplified procedure A roentgen film devoid of contrast medium is chosen from the films obtained during rapid serial angiography A positive of this is made, and development and fixation of it takes place together *with* the ordinary roentgen films in an



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Fig 4 Capillary phase characterized by a wavy appearance of the cortical structures

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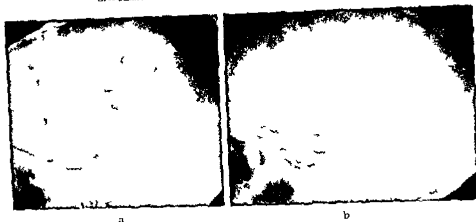


Fig 6 a) The cortical structures in the occipital and lower temporal regions are not demonstrated when the posterior cerebral artery is not filled b) The posterior cerebral artery is filled with contrast medium and the occipital and lower temporal cortical structures are stained

cortex on the contralateral side of the midline is also outlined This is due to the fact that the medial aspects of both hemispheres peripherally are vascularized from the right pericallosal artery When the pericallosal artery is not filled with contrast medium the corresponding part of the cortex is not distinguishable in the capillary phase (Fig 2a)

The structures supplied by the posterior cerebral artery add to the appearance of the capillary phase in the a p view when this artery is filled from the internal carotid artery A density corresponding to the under surface of the temporal lobe may thus be distinguished The visibility of structures along the midline is also dependent on whether contrast medium has reached the posterior cerebral artery In Fig 2b the posterior cerebral artery was filled during vertebral angiography, and it can be seen that a wide region close to the midline is stained bilaterally with contrast medium

The central grey matter of the brain is likewise supported with a rich and dense capillary network It is probable that these structures also participate in the capillary phase although it has to date been possible only exceptionally to differentiate them from superimposed cortical structures

The lateral ventricles also partake in the appearance of the capillary phase although distinct limits are usually not apparent in the ordinary a p view due to superimposition of cortical structures In a half axial view the cortical structures are more separated and the border of the lateral ventricle is well outlined The part most clearly seen is the lateral wall of the cella media which is delimited by the caudate nucleu (Fig 3)

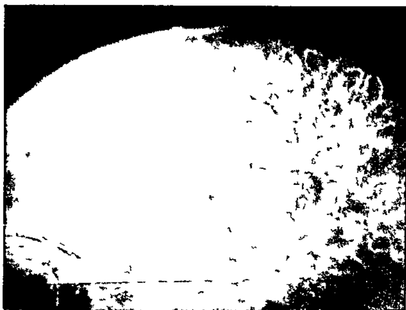


Fig. 3. Diffuse staining of the cortex surrounds small arteries in the capillary phase. The corpus callosum is devoid of medium and the cortical structures surrounding the Sylvian fissure produce a denser area.

automatic processing unit. This procedure enables us to take advantage of the subtraction method already at the time of the examination. The positive is placed on top of the negative roentgen films, one after the other, as obtained in rapid serial angiography. This technique of scrutinizing all the films in their sequence soon revealed that there is a substantial capillary phase and not one characterized by homogenous staining of the cerebral structures. Moreover, the capillary phase may be clearly seen in the a.p. as well as in the lateral views.

Appearances of the capillary phase

A.p. view. A seemingly diffuse staining of the injected half of the brain is apparent in the a.p. views. When the roentgen films are examined closely and especially when the subtraction method is applied, it is possible to distinguish the cortex from the medulla of the cerebrum, as all bony structures disappear and the differences in density between the grey and white substance stand out clearly. The cortex is richer in capillaries than the medullary substance and the cortex is therefore seen on the roentgen films as a band of density, outlined against the medullary substance medially and the calvarium laterally (Fig. 1a).

The distribution of the capillary phase is dependent upon what areas of the brain are reached by the contrast medium. In Fig. 1b, a small region of the



Fig 6 a) The cortical structures in the occipital and lower temporal regions are not demonstrated when the posterior cerebral artery is not filled b) The posterior cerebral artery is filled with contrast medium and the occipital and lower temporal cortical structures are stained

cortex on the contralateral side of the midline is also outlined This is due to the fact that the medial aspects of both hemispheres peripherally are vascularized from the right pericallosal artery When the pericallosal artery is not filled with contrast medium the corresponding part of the cortex is not distinguishable in the capillary phase (Fig 2a)

The structures supplied by the posterior cerebral artery add to the appearance of the capillary phase in the a p view when this artery is filled from the internal carotid artery A density corresponding to the under surface of the temporal lobe may thus be distinguished The visibility of structures along the midline is also dependent on whether contrast medium has reached the posterior cerebral artery In Fig 2b the posterior cerebral artery was filled during vertebral angiography and it can be seen that a wide region close to the midline is stained bilaterally with contrast medium

The central grey matter of the brain is likewise supported with a rich and dense capillary network It is probable that these structures also participate in the capillary phase although it has to date been possible only exceptionally to differentiate them from superimposed cortical structures

The lateral ventricles also partake in the appearance of the capillary phase although distinct limits are usually not apparent in the ordinary a p view due to superimposition of cortical structures In a half axial view, the cortical structures are more separated and the border of the lateral ventricle is well outlined The part most clearly seen is the lateral wall of the cella media which is delimited by the caudate nucleus (Fig 3)



Fig [illegible] Diffuse staining of the cortex surrounds small arteries in the capillary phase The corpus callosum is devoid of medium and the cortical structures surrounding the Sylvian fissure produce a denser area

automatic processing unit This procedure enables us to take advantage of the subtraction method already at the time of the examination The positive is placed on top of the negative roentgen films, on one after the other, as obtained in rapid serial angiography *This technique of scrutinizing all the films in their* sequence soon revealed that there is a substantial capillary phase and not one 'characterized by homogenous staining of the cerebral structures Moreover, the capillary phase may be clearly seen in the a p as well as in the lateral views

Appearances of the capillary phase

A p view A seemingly diffuse 'staining' of the injected half of the brain is apparent *in the a p views When the roentgen films are examined closely* and especially when the subtraction method is applied, it is possible to distinguish the cortex from the medulla of the cerebrum, as all bony structures disappear and the differences in density between the grey and white substance stand out clearly The cortex is richer in capillaries than the medullary substance and the cortex is therefore seen on the roentgen films as a band of density, outlined against the medullary substance medially and the calvarium laterally (Fig 1a)

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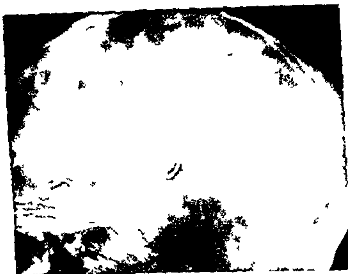


Fig 8 Large avascular t mporal lobe tumour around hich the gyri and sulci are seen to be deformed and displaced

phase is almost never seen This may be explained by several facts The frontal veins are filled with contrast medium before the occipital veins, the same sequence is also evident in the appearance of the capillary phase It is also apparent that the capillary phase starts before the arteries are quite free from contrast medium As the capillary network successively fills the smaller pial arteries are often outlined at the same time peripherally this is well demonstrated in lateral views The small pial arteries appear to be surrounded by a diffuse band of contrast medium for a shorter or longer distance (Fig 5) No sharp limit to the venous phase is apparent Even the small veins collect in the sulci and are evident in the same positions as the peripheral parts of the pial arteries surrounded by a staining of the cortex.

The cerebral ventricles and the white substance of the brain mould the appearances of the capillary phase even in the lateral view The corpus callosum may sometimes be clearly distinguished and the grey centres together with the cortical substance surrounding the Sylvian fossa will occasionally appear as a denser area (Fig 5)

The posterior cerebral artery contributes a great deal to the appearances of the capillary phase in the lateral view When this artery is not filled with contrast medium the capillary phase corresponding to the occipital and lower part of the temporal lobes is missing and the staining of the posterior part of the parietal region is faint (Fig 6a) When the posterior cerebral artery

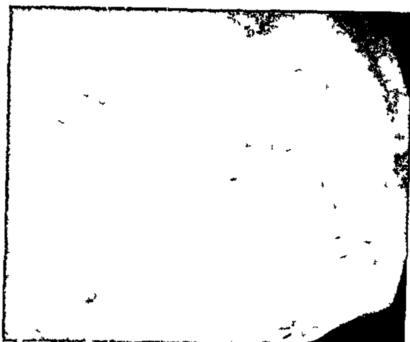


Fig 7 Vertebral angiography capillary phase The region supplied by the posterior cerebral artery is also stained

The capillary phase as it appears in the a p view is limited to those parts of the cortex that are more or less parallel to the central beam The cortical areas *in the frontal and occipital regions of the brain cannot be well demon*strated unless the examination also includes oblique views

Lateral view The capillary phase as it appears in the lateral view seems to provide less information than in the a p views The appearance is quite different from that in the latter and the contrast between the various parts less obvious Close scrutiny will however reveal that a detailed representation of the surface of the brain has been obtained The capillary phase in the lateral view (Fig 4) is characterised by a wavy appearance corresponding with the pattern of the gyri and sulci The denser regions are formed by the parts of the cortex surrounding the sulci and not by the summits of the gyri The slopes of the *sulci appear denser than the summits of the gyri and the depths of the sulci,* since they are parallel to the central beam direction for a much longer distance and a greater absorption of roentgen rays is obtained This is the explanation of the surprisingly large number of dense regions that are seen in a lateral view The gyri on the medium surface of the brain, as they are projected on top of the gyri on the lateral aspect, accentuate the densities

In agreement with earlier investigators, the author feels that a true capillary



Fig 11 Area devoid of cortical structures corresponds to posterior frontal gyrus (Probably chemical lesion no autopsy)

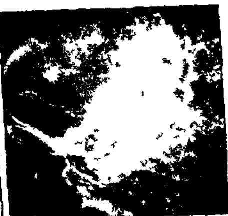


Fig 12 A large avascular area devoid of cortical structures is seen frontally (Probably ischemic lesion no autopsy)

have reported that occlusions of small arteries may be demonstrated by rapid serial carotid angiography especially when a stereo technique is used Infarctions may however exist without any occlusion of the arteries demonstrable at carotid angiography An identification of an avascular area in the capillary phase opens up new possibilities for demonstrating infarctions by carotid angiography

The appearances of a large hemorrhagic infarction in the capillary phase is demonstrated in Fig 10 The clinical history suggested a haemorrhage in the left hemisphere Carotid angiography was performed several weeks after the acute onset of the signs A large avascular process was demonstrated in the parietal region and in the capillary phase this region was wholly devoid of cortical structures Staining of the cortex was evident in the areas surrounding the avascular region in which a few arteries emptied very slowly, without any capillary phase appearing in the subsequent films The patient died following further cerebral ischemia Necropsy revealed evidence of an old hemorrhagic infarction in the parietal lobe corresponding to the mass demonstrated at the radiologic examination The cortex was largely *involved*

The next patient had all the clinical signs of cerebral ischemia involving the motor region No expansive process was evident at carotid angiography The Rolandic artery was not seen and in the capillary phase the region corresponding to the motor area was devoid of cortical structures (Fig 11) The patient is still alive and infarction has not been confirmed

A large frontal avascular region was demonstrated at carotid angiography in a third patient (Fig 12) No cortical structures could be identified in this

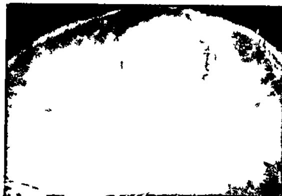


Fig 9 A parasagittal meningeoma has moulded a cavity in the brain substance and the surrounding gyri are deformed and displaced

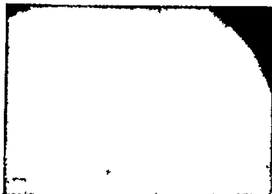


Fig 10 Large hemorrhagic infarction in parietal region completely devoid of cortical structures Faint staining surrounds part of avascular area

fills with contrast medium, the occipital and lower regions of the temporal lobe become visible (Fig 6b)

A capillary phase is also distinguishable in vertebral angiography (Fig 7), although its details have not yet been studied The region supplied by the posterior cerebral arteries is however well stained

It is understandable that the appearances of the capillary phase change in connection with ischemic lesions of the cortex Expanding lesions affecting the surface structures of the brain will also influence the capillary phase Such changes are well known in avascular tumours and hemorrhagic processes, where the affected regions appear devoid of vessels, but it is less well known that characteristic changes are also evident during the capillary phase

The appearances of the capillary phase, in a large avascular intracerebral tumour in the temporal lobe, is illustrated in Fig 8 In the arterial phase, the medial cerebral artery and its peripheral branches are markedly displaced around the tumour A large area, devoid of medium and surrounded by deformed and displaced gyri, is seen in the capillary phase

Even an extracerebral tumour, i e a meningioma, will give rise to changes in the capillary phase A parasagittal meningioma has moulded a cavity in the brain substance, in which the tumour is located as seen in Fig 9 This lateral view shows the capillary phase, in which the gyri surrounding the growth appear deformed and displaced

The main interest lies in the demonstration of infarctions or ischemic areas in the brain substance The general opinion appears to be that infarctions can seldom be demonstrated by carotid angiography even if the clinical signs point to a defined area of the brain This may be due to many factors Knowledge of the variations in the small peripheral arteries is scanty LANNER & ROSENGREN



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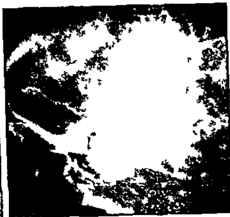


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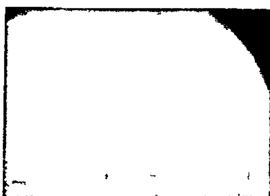


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region, the process was only slightly expansive Infarction, possibly in combination with hemorrhage, was suggested The patient, who was markedly hypertensive, gradually recovered, and further carotid angiography four weeks later revealed signs only of a large avascular frontal area without any obvious capillary phase No occlusion of any vessels could be demonstrated but the arteries were grossly dilated, elongated and irregular The clinical signs even in this patient have to a great extent disappeared The slight displacement of the pericallosal artery is no longer apparent and the central veins are not displaced although a large avascular area is still demonstrable

Conclusions

Although a pure capillary phase is rarely seen, some such sort of phase is always evident in rapid serial angiography This may be a phase in which most of the medium appears in the capillary network, and if the subtraction method is applied it provides information regarding the shape and pattern of the cortical structures Deformation and displacement of cortical structures as well as ischemic regions in the cortex of the brain substance may also be distinguished

SUMMARY

The capillary phase in cerebral angiography and a technique for its investigation based on the subtraction method in combination with rapid serial angiography are described The normal appearances of the cerebral structures their variation due to varying vascular supply and changes caused by expanding lesions and ischemic processes are discussed

ZUSAMMENFASSUNG

Die kapillare Phase der Gehirnangiographie wurde mittels rascher Serienfilme und mit der zusätzlichen Hilfe der Subtraktionsmethode studiert Das normale Röntgenbild der Gehirnstrukturen und solche Varianten wie sie ein wechselnder Blutzufluss oder raumbeengende Prozesse oder eine gestörte Blutversorgung hervorbringen werden beschrieben

RÉSUMÉ

Description de la phase capillaire de l angiographie cérébrale et d une technique destinée à l étudier basée sur la méthode de soustraction avec angiographie en série rapide L auteur examine les aspects normaux des structures cérébrales leurs variations dues aux variations de l apport vasculaire et les modifications causées par les lésions expansives et les processus ischémiques

metrizoate was reduced by the replacing of a small fraction of the sodium ions by calcium and magnesium ions known to be antagonistic in certain respects to sodium ions. The greatest reduction in toxicity, as measured by intravenous injection in the rabbit, was obtained when the amounts of calcium and magnesium in the contrast medium were two to three times their concentration in human plasma, while the ratio of calcium and magnesium ions to each other was the same as in plasma.

We have compared the sodium metrizoate and the sodium metrizoate solution to which has been added calcium and magnesium ions in a carefully controlled group of animal injection studies.

Methods. The 52 % concentrations of the two contrast media (sodium metrizoate in 52 % concentration has the same amount of iodine as 50 % sodium diatrizoate) were compared in ten adult dogs weighing 8.5 to 15 kg and anesthetized with intravenous nembutal. Two relatively high doses, 0.5 and 1.0 ml/kg bodyweight, were chosen to produce changes of a degree suitable for measurement since the purpose was to compare the two media against each other and not to relate the results quantitatively to previous studies. Each dog was injected with two doses of the two compounds, the order of injections being randomized.

The actual injection technic and equipment were essentially the same as described previously by FISCHER & ECKSTEIN (1961) except that the respiration was not assisted or controlled by a respirator pump. Arterial blood pressure and electrocardiogram were recorded simultaneously on the Sanborn direct writing oscillograph. Since venous pressure and end expiratory CO_2 measurements reflect the same basic disturbances as heart rate and rhythm and blood pressure alterations, they were not included in order to simplify the experiment. The individual injection times and the actual injection pressure of 128 pounds per square inch with the Shipp's apparatus were the same for the two media. The responses were measured from the recordings without knowledge of the sequence of injections. The averages of all animals were plotted on graph paper as dose response curves.

Results

The averaged values of the two doses are shown in the accompanying graphs (Figs. 1 to 4). The measurements are expressed as change in heart rate, duration of the longest asystole, the total duration of irregular heart action, duration of major pulse and blood pressure changes, and decrease in diastolic and mean arterial blood pressure. All of the measurement

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TOXICITY STUDY OF SODIUM METRIZOATE CONTAINING CALCIUM AND MAGNESIUM

by

HARRY W. FISCHER and STEVEN H. CORNELL

The search for angiographic contrast media of the lowest toxicity continues. It has earlier been shown by many investigators that the diatrizoate compounds in comparison with acetrizoate compounds cause less disturbance of heart rate, less lowering of blood pressure and cardiac output, and less elevation of venous pressure. FISCHER & ECKSTEIN (1961) have reported that methylglucamine diatrizoate was found to be better tolerated than the sodium salt but it has the disadvantage of being quite viscous when prepared in the highly concentrated solutions as are considered useful in angiocardiography and aortography. More recently, two other high iodine content contrast media, iothalamate and metrizoate, have been introduced and early tests have shown them to be of low toxicity. However, their low viscosity sodium salts likewise appear to be less well tolerated than their more viscous methylglucamine salts (BERNSTEIN et coll. 1962, BUSFIELD et coll. 1962, FOSTER et coll. 1964, KODAMA et coll. 1963, PATTINSON 1962). HOLTERMANN & SALVESEN (unpublished data) have advanced the concept of the excess of sodium ions being responsible for part of the toxic effects of an intravascular contrast medium and they have reported that the toxicity of sodium

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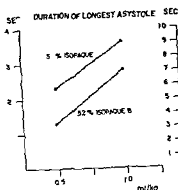


Fig 2

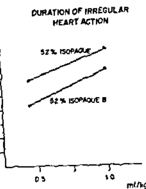


Fig 3

Fig 2 Longest periods of asystole caused by the intra carotid injection of 0 5 and 1 0 ml/kg doses of Isopaque and Isopaque B

Fig 3 Periods of irregular heart action following injections of 0 5 and 1 0 ml kg doses of Isopaque and Isopaque B

Decrease in diastolic arterial blood pressure was obtained by observing the lowest diastolic pressure after injection and comparing with the diastolic pressure immediately prior to injection The decrease following injection of the small and large doses of Isopaque were 58 and 63 mm Hg the figures for Isopaque B were 42 and 57 mm Hg (Fig 4c)

Decrease in mean arterial blood pressure at the point of greatest blood pressure fall compared to the pre injection levels was 38 mm Hg for the 0 5 ml/kg dose of Isopaque and 42 mm Hg for the larger dose The figures for the corresponding doses of Isopaque B were 29 and 36 mm Hg The mean pressure value reflects the decrease in diastolic pressure and the over swing of the systolic pressure reading preceding the greatest diastolic drop (Fig 4d)

Discussion

Previous studies by Holtermann & Salvesen (unpublished) have shown that a sodium metrizoate solution with small amounts of calcium and magnesium ions raised the LD for intravenous injection in the rabbit about 100 % or to about the same level as the LD_{50} for the methylglucamine metrizoate compound The addition of calcium and magnesium ions to sodium metrizoate reduced or eliminated the depressive effect on myocardial tissue observed with sodium metrizoate sodium and methylglucamine diatrizoate and sodium acetrizoate in perfusion studies on the isolated rabbit heart In blood brain barrier testing in the rabbit sodium metrizoate with added calcium and magnesium was less toxic than sodium metrizoate or sodium diatrizoate However no significant difference in skin irritancy was found between the

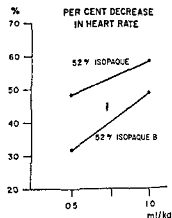


Fig 1 Decrease in dog s heart rate following 0 5 and 1 0 ml/kg doses of Isopaque and Isopaque B injected into the carotid artery The rate for a 6 sec period after injection was compared to the pre injection rate Isopaque B differs from Isopaque only in the replacement of a small portion of the sodium ions by calcium and magnesium ions The values are averages of experiments in ten dogs

magnesium metrizoate (Isopaque B) and larger changes resulting from the 1 0 ml/kg doses as compared to the 0 5 ml/kg doses

Decrease in heart rate for the 6 sec period following the first detectable change in rate was arbitrarily chosen and compared to the rate for a 6 sec period before injection (Fig 1) The rate change was expressed as a percent decrease of the pre injection value The two doses of Isopaque caused 48 3 and 58 4% decrease in heart rates while the Isopaque B solution caused a decrease of 31 8 and 49 2 %, respectively

Duration of longest asystole caused by the 0 5 ml/kg dose of Isopaque was 2 3 sec and by the 1 0 ml/kg dose 3 6 sec (Fig 2) In comparison, the periods of asystole for Isopaque B were 1 3 and 2 6 sec

Duration of irregular heart action The interval from the first pulse change to the cessation of irregular cardiac rhythm was 6 0 and 8 1 sec for two doses of Isopaque, and 4 3 and 6 8 sec for Isopaque B (Fig 3)

Duration of major heart rate change was based on the observers estimations of these changes from the recordings Since it was often difficult to determine what constitutes a major change, this measurement was not as precise as those described above The two doses of Isopaque caused major heart rate changes of 5 and 6 7 sec, and the two doses of Isopaque-B, 2 9 and 5 7 sec (Fig 4a)

Duration of major arterial blood pressure change likewise suffered from a relative imprecision of measurement The smaller dose of Isopaque resulted in an abnormal blood pressure of 4 5 sec duration, the larger 6 3 sec duration The corresponding values for Isopaque B were 2 6 and 4 7 sec (Fig 4b)

agent is simpler and more sensitive than blood brain barrier EEG or cerebral blood flow studies but nevertheless provides data which are in agreement with the more complex evaluations of relative toxicity of contrast media The contrast medium which produces the lesser cerebral disturbance is to be preferred for clinical use Also there should be a preference for a medium which produces the least alteration in blood pressures cardiac rates rhythm and output for increased morbidity may be related to any appreciable deviations of this nature particularly in the patient with lessened cardiac reserve Although the differences between the two preparations were not as great as seen on certain previous comparisons of different contrast solutions we consider the differences significant The dose response curves might have been more steep and the differences between the two curves greater if smaller doses had been tested that is the present values might be at the upper portion of a dose response curve

Since the two tested contrast solutions were identical in iodine content viscosity and anionic chemical structure and differed only in their cation composition further weight is therefore given to the idea that calcium and magnesium ions lower the toxicity of an intravascular contrast medium The manner in which the sodium ions enhance the toxicity of a contrast medium is not yet known Excessive sodium ions may increase the permeability primarily of the capillaries or secondarily of other cells allowing more easy and rapid entrance of the iodinated anionic organic molecule into the tissue fluids or into the tissue cells there to exert its toxic effect (GENSINI & DIGIORGI 1964 HOLTERMANN & SALVESEN unpublished data)

The protective effect of calcium and magnesium ions probably results from their limiting the permeability increase brought on by the high concentration of sodium ions The methylglucamine ion which also gives a protective effect for the anionic part of the contrast media may do so because it does not alter the permeability of capillaries or cells or because its size interferes with the movement of the anion (GENSINI & DIGIORGI)

Acknowledgements

The Isopaque and Isopaque B contrast media were furnished to us by Dr Hugo Holtermann Nyegaard & Company Oslo Norway

SUMMARY

Lesser disturbances in heart rate and arterial blood pressure were produced by carotid injection in the dog of a sodium metrizoate containing calcium and magnesium than by a pure sodium metrizoate solution supporting the concept that these bivalent ions reduce that portion of toxicity of an angiographic agent which is thought to be due to an excess of sodium ions

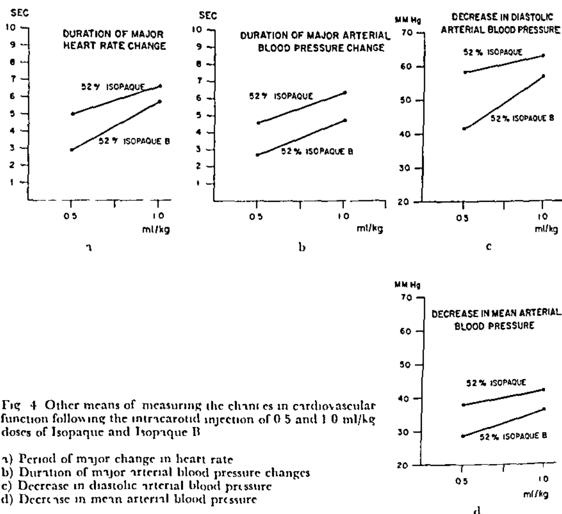


Fig. 4. Other means of measuring the changes in cardiovascular function following the intracarotid injection of 0.5 and 1.0 ml/kg doses of Isopaque and Isopaque B.

a) Period of major change in heart rate
b) Duration of major arterial blood pressure changes
c) Decrease in diastolic arterial blood pressure
d) Decrease in mean arterial blood pressure

two preparations, nor was there difference in renal toxicity between the two as measured by a modified Idbohrn test.

The measurements of heart rate and arterial blood pressure following injection into the carotid artery of two dose levels of the pure sodium metrizoate and the sodium metrizoate preparation with added calcium and magnesium showed the latter to be better tolerated by the animal. The several measurements are merely different ways to gauge the vagal effect, the animal's response to the entry into the cerebral circulation of a noxious compound, which has previously been shown to be mediated through the vagus nerves by LINDGREN & TORNELL (1958). The averaged values in each set of measurements consistently revealed approximately the same responsiveness. We assume that the degree to which the animal responds in this manner depends upon the severity of the cerebral disturbance. This particular method of testing an angiographic

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The Isopaque and Isopaque B contrast media were furnished to us by Dr Hugo Holtermann Nyegaard & Company Oslo Norway

SUMMARY

Lesser disturbances in heart rate and arterial blood pressure were produced by carotid injection in the dog of a sodium metrizoate containing calcium and magnesium than by a pure sodium metrizoate solution supporting the concept that these bivalent ions reduce that portion of toxicity of an angiographic agent which is thought to be due to an excess of sodium ions

ZUSAMMENFASSUNG

Injektion von Ca und Mg enthaltendem Natriummetrizoat in die A. carotis von Hunden verursachte geringere Störungen des Herzrhythmus und des arteriellen Blutdruckes als die Injektion von reiner Natriummetrizoatlösung. Dies stützt die Annahme, dass diese bivalenten Jonen den Teil der Toxizität eines angiographischen Präparates verringern, der auf einem Überschuss von Natriumjonen beruhen dürfte.

RÉSUMÉ

L'injection carotidienne d'un métrizoate de sodium contenant du calcium et du magnésium a donné chez le chien des modifications du rythme cardiaque et de la tension artérielle moins *importantes que celles qui sont dues à une solution pure de métrizoate de sodium*; ceci confirme l'hypothèse que ces ions bivalents réduisent la partie de la toxicité du moyen de contraste que l'on suppose due à un excès d'ions sodium.

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PELVIC ANGIOGRAPHY AND PNEUMOPERITONEUM IN THE DIAGNOSIS OF GYNECOLOGIC LESIONS

by

CLAES RADBERG and INGMAR WICKBOM

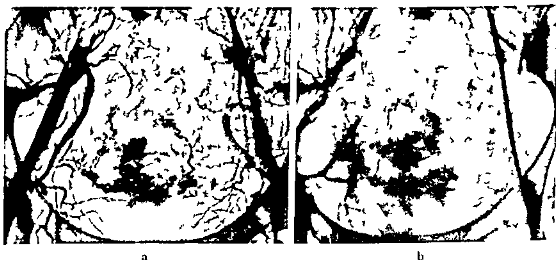
Roentgenologic methods have not been widely used in the examination of gynecologic tumours probably partly due to the fact that these are generally palpable An experienced gynecologist can usually differentiate between an ovarian tumour and a myoma of the uterus with a fair degree of certainty In recent years laparascopy and culdoscopy, allowing direct insp ction of the tumour have also been more widely used although there are cases where even these methods fail to give a clear idea of the true nature of the lesion It is the purpose of this communication to discuss the value of the two roent genologic methods of pneumoperitoneum and pelvic angiography The former has been recommended especially by French Italian and German authors (BETOULIÈRES et coll 1955 BRAIBANTI 1960 HERBEAU & VERHAEGHE 1957, MARCHESI et coll 1955 MURPHY JR et coll 1964 VALLEBONA & DOGLIOTTI 1937) but it appears that only a small series of cases have so far been presented Pelvic angiography seems to have been more widely employed in recent years thanks to improvements in angiographic techniques and roentgen contrast media BORELL & FERNSTROM (BORELL et coll 1952 BORELL & FERNSTROM

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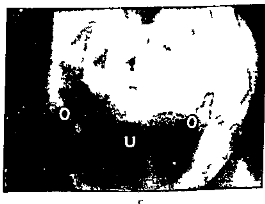


a b

Fig. 1. Patient aged 45. a) Arterial phase and b) late phase. Myomatous uterus of typical appearance with arch-like stretching of the intramural arteries. Defects in contrast loading is evident in the late phase and represent necrotic or fibrotic parts of the tumour.



a b



c

Fig. 2. Patient aged 47. a) and b) Angiography. Uterus somewhat enlarged and of typical myomatous appearance. The right uterine artery, which is somewhat larger than the left, fills several vessels to the right of the uterus. c) Pneumoperitoneum. The ovaries (O) are of normal size and the large tumour behind the uterus (U) must therefore be a subserous myoma. (Confirmed at operation.)



a



b

Fig 3 a) Patient aged 51 Bilaterally hypertrophic adnexal branches give off irregular tumour vessels (→) Uterus is denoted by U Malignant ovarian tumour (confirmed at operation) b) Patient aged 40 The adnexal branch (←→) as well as the ovarian artery (→) on the left side are hypertrophic they follow a wavy course and give off small irregular vessels (At operation a cystic ovarian tumour with a small solid part was found on the left side and microscopy proved it to be a pseudomucinous cystadenoma

1953 1954 HERBEAU & VERHAEGHE 1957 FERNSTROM 1955) have been prominent in evolving a suitable angiographic technique and in studying the normal anatomy as well as changes present in different pathologic conditions

Methods and Materials Pelvic angiography has been performed in our department in some 270 cases of gynecologic masses of more or less obscure nature An additional examination with pneumoperitoneum was performed in a little more than 50 of these cases In some further cases the latter method alone was used

The angiographic technique is briefly as follows A radio opaque catheter (yellow Odman) is inserted percutaneously and advanced about 22 cm so that the tip comes to lie at or just above the aortic bifurcation The contrast medium as a rule 10 ml Urografin 60 % is injected at a pressure of 3 to 4 kg cm² the femoral arteries being compressed in the ...



a



b

Fig. 4. Patient aged 58. a) Only the pelvic arteries are filled (tip of catheter at aortic bifurcation). Right uterine artery (→) very thin, left normal, uterus enlarged. b) With catheter further introduced the hypertrophic right ovarian artery (→) filled and is seen to supply the uterus as well as a highly vascular ovarian tumour (→). (Operation revealed a partly cystic partly solid carcinoma of low differentiation.)

Using a film changer, 12 to 16 films are obtained alternately with two tubes forming an angle of 8° and receiving current from separate transformers. In this way, pairs of films that can be viewed stereoscopically are obtained. The films of each pair are generally separated by a quarter or half a second interval, with the first pair obtained at the end of the injection and the last 7 to 8 sec later. The examination is sometimes completed with a series of films obtained after the catheter has been advanced another 10 cm so that the ovarian arteries become filled, the amount of medium is then increased to about 50 ml.

Anatomy. The uterine artery arises from the internal iliac artery near the pelvic wall, it passes through the parametrium to the isthmus of the uterus and then swings upwards to follow the lateral walls of the uterus in which it gives off many typical corkscrew intramural branches. The adnexal branches arise at the horn of uterus and run upwards and laterally. Together with the ovarian artery they supply the tube and the ovary, only one of the adnexal branches on each side is generally visible at angiography. The ovarian artery



Fig 5 Patient aged 3? Ectopic pregnancy six to seven weeks old Placental sinuses (→) and wide draining vein (←) are seen to the left and below the uterus (U) Cystic corpus luteum (→→) of typical appearance at the pelvic inlet on the same side

arises from the renal artery or more often from the aorta in the latter case usually distal to the renal artery The ovarian artery and adnexal branches of the uterine artery supply adnexal structures within a variable range and may become interchangeable in function The ovarian artery is usually easily identified from its typical small wave course The superficial epigastric artery runs a similar course but its anterior location can be seen by means of stereoscopy Stereoscopic films appear to the authors to be invaluable in pelvic angiography not least for the assessment of adnexal branches these latter may sometime be difficult to identify and distinguish from other pelvic arteries



Fig 6 Patient aged 58 The right ovarian artery (→) is hypertrophic and supplies a number of irregular vessels (→→) (Operation revealed the tumour to be an ovarian fibroma)

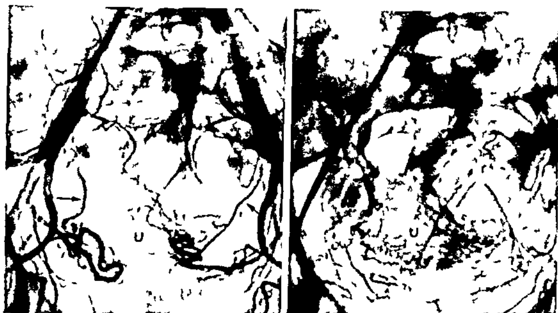


Fig 7 Patient aged 19 with pain and anaemia left palpable mass Hypertrophic left adnexal branch (→) displaced around an area the central part of which is avascular while the periphery is rich in vessels The right adnexal branch (→) is also somewhat hypertrophic Uterus (U) Bilateral salpingitis (confirmed at operation)

Pneumoperitoneum Two to three litres of oxygen are usually injected intraperitoneally The films are generally obtained with the pelvis elevated in both the face up and face down positions in order that gas surround all the parts to be examined When interpreting the films it is important to bear in mind that the pelvic organs are to some degree mobile and that accordingly they alter in position with the varying positions of the patient No standardized technique is therefore used but after perusal of the initial films the attempt is made to determine the projection and position most likely to be suitable The patient is sometimes placed in the recumbent position so as to cause the organ to be examined to fall back towards the lesser pelvis Most information is usually gained with the patient prone and with the pelvis elevated Oblique films are often necessary to project the different organs free from one another, and tomography may often be of great help The tomograms should then be obtained in the position already been found to be the most satisfactory one A barium enema or gas insufflation of the colon or bladder may assist in differentiating these from the genital organs

The angiographic technique, as in other parts of the body, is based on vascular displacement and the presence of newly formed tumour vessels It is also of importance to determine what vessels supply the lesion A vascular supply from the uterine artery itself usually indicates a myoma (except in rare cases



Fig 8 Patient aged 24 with irregular bleeding abdominal pain and a tender mass to the left Hypertrophic left adnexal branch (projected over the uterine artery) gives off wide tortuous branches (→) to the wall of the dilated Fallopian tube the right adnexal branch is also hypertrophic and tortuous (→) Uterine artery (⟷) uterus (U) (Operation revealed salpingitis predominantly on the left side)

of malignant tumours such as myosarcomas and chorionepitheliomas) An ovarian tumour on the other hand is supplied by the adnexal branch of the uterine artery or by the ovarian artery It should however as mentioned before be borne in mind that the ovarian artery sometimes contributes to the vascular supply of the uterus Myomas are at least in younger subjects often highly vascular and then usually have typical angiographic appearances represented by numerous small irregular vessels and an arch like stretching of the intramural branches These vessels are often better filled after the administration of Priscoline (through the catheter) In a later phase the myoma often appears almost stained with contrast medium Part of the tumour may be avascular due to degenerative changes (Fig 1) An intramural myoma may be detected even if it is fibrotic or completely necrosed as an avascular area surrounded by stretched intramural vessels A poorly vascularized subserous myoma on the other hand cannot be diagnosed with certainty by angiography alone Pneumoperitoneum is then more useful as illustrated in Fig 2

Malignant ovarian tumours often contain irregular vessels at least in part of the tumour which may be supplied by adnexal branches of the uterine artery (Fig 3a) the ovarian artery (Fig 4) or by both (Fig 3b) The importance of demonstrating the ovarian artery is evident from Fig 4

Increased vascularity of the adnexal does not necessarily indicate a malignant lesion It can for example appear in a corpus luteum (Fig 5) and in an ovarian fibroma (Fig 6) The placental sinuses usually have rather typical appearances

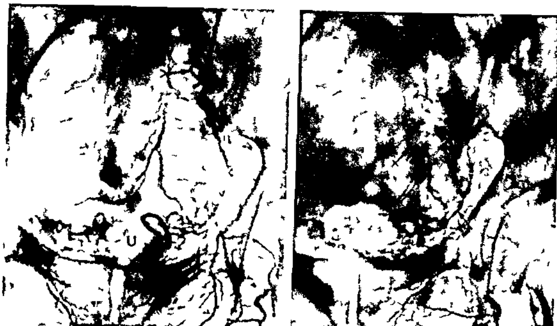


Fig 9 Patient aged 43 Hypertrophic left adnexal branch (→) displaced around an area (↔) the central part of which is avascular while the periphery is rich in vessels The ovarian artery (↣) on the same side is somewhat hypertrophic and so is the right adnexal branch Uterus (U) (Left hydrosalpinx with numerous small abscesses in a thickened wall were disclosed at operation)



Fig 10 Patient aged 39 a) Angiography Uterus is enlarged myomatous and deflected to the left no definite filling of adnexal branches on either side right ovarian artery (→) filled but no tumour vessels are evident b) Pneumoperitoneum Rounded soft tissue mass (S) above and to the right of the enlarged uterus (U) Ovaries not demonstrated (Operation revealed a large right cystic ovary and myomatous uterus the left ovary had been removed earlier because of salpingo oophoritis)



Fig 11 P tient aged 54 a) Ang ography Uterus (U) somewhat enlarged and deflected to the right No demonst at on on e ther side of adnexal branches or ovarian arteries b) Pneumoperitoneum Left ovary (S) enlarged and rounded right ovary (O) of normal s ze and uterus (U) somewhat enlarged (Operat or d clos d an ovar an cyst on the left si le)



Fig 12 Pat ent ag d 46 Large rregular tumour (S) above a moderately enlarged and myomatous uterus (U) The ma s conta ns several i regular vessels f om the hypertrophic adnexal branches (→) on both s des Ovar es not dent f ed (Operation revealed bilateral ovarian carci ioma closely connect d ith the enla ged uterus)

in ectopic pregnancy (Fig 5) It seems to be less well known that salpingitis may also appear as a richly vascularized lesion (Figs 7 8 and 9)

Ovarian cysts and poorly vascularized ovarian tumours cannot be demonstrated with certainty at angiography even if the adnexal branch and (or)



a b

Fig. 13. Patient aged 46. a) Angiography. Uterus (U) displaced to the right. Hypertrophic left uterine artery (→) displaced in a wide circle continues in a large adnexal branch (←→) anastomosing with a widened ovarian artery (→→); it gives rise to several irregular branches. b) Pneumoperitoneum. Large soft tissue tumour (S) to the left of the uterus (U). Left ovary not identified, right ovary normal. (Operation revealed an intraligamental ovarian tumour.)



a a

Fig. 14. Patient aged 44. a) Angiography. Hypertrophic left uterine artery (→) displaced as in fig. 14 gives off several branches, one of which (+→) follows the same course as the main artery. Ovarian artery not visible. Uterus (U). b) Pneumoperitoneum. An enlarged uterus (U) is closely connected below (M) and to the left (M) of two rounded tumours. Fallopian tube in the broad ligament (→) displaced upwards by one of the growths, to the left of which the left ovary (+→) is situated and appears normal. The right ovary (→→) is also not obviously abnormal. (Operation revealed the two tumours to be myomas, one of them lay in the broad ligament.)

the ovarian artery may be somewhat hypertrophic in these tumours also They are however usually revealed by pneumoperitoneum which method therefore may be useful in the differential diagnosis between poorly vascularized myomas and ovarian tumours (Figs 10 and 11)

The two methods may sometimes supplement each other, as is shown in Fig 12 The patient had for several years been known to have a myomatous uterus and during the few weeks preceding the examinations had experienced a rapid increase in abdominal girth ascites was noted clinically Palpation revealed a large pelvic tumour Pneumoperitoneum revealed a large mass which could not be differentiated from the enlarged uterus no evidence of normal ovaries Angiography disclosed irregular vessels from the hypertrophic adnexal branches High vascularity does not necessarily mean a malignant tumour as mentioned before, but benign tumours are never so closely connected

It may be extremely difficult even at operation to differentiate between a myoma and an ovarian tumour when these are situated in the broad ligament This is exemplified in Figs 13 and 14 which illustrate two very similar angiographic cases The first case proved to be one of a cystadeno carcinoma and the other one of a myoma

Discussion

Myomas of the uterus usually have a rather typical vascularization generally from the uterine artery itself They are sometimes more or less avascular due to partial necrosis or fibrosis

Malignant ovarian tumours are generally at least partly highly vascular and supplied by the adnexal branches of the uterine artery the ovarian artery or both

It should be borne in mind however that benign ovarian tumours such as fibromas as well as a corpus luteum and inflammatory lesions may also be highly vascular

Pneumoperitoneum will usually indicate whether the tumour arises from the uterus or from the adnexa so that this method is more informative in poorly vascularized lesions

The two methods thus complement each other and may sometimes both be needed to permit definite conclusions to be drawn

SUMMARY

The value of pelvic angiography and pneumoperitoneum in the examination of gynecologic disorders is discussed It is shown that the two methods may often be complementary

ZUSAMMENFASSUNG

Der diagnostische Wert des Pneumoperitoneums und der Beckenangiographie wurden bei gynaekologischen Fällen verglichen. Es wird hervorgehoben dass bei Verwendung beider Methoden die Diagnose oft verbessert werden kann.

RÉSUMÉ

Les auteurs étudient l'intérêt de l'angiographie pelvienne et du pneumopéritoine dans le diagnostic des affections gynécologiques. Ils montrent que ces deux méthodes peuvent souvent se compléter.

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HYSTEROGRAPHIC CHANGES FOLLOWING TRANSVERSE LOWER SEGMENT CAESAREAN SECTION

by

H. SCHIØLER, M. EIKEN, BJ. OVLISEN and D. TROLLE

It is now common practice to attempt vaginal delivery after transverse lower segment caesarean section provided there are no contra-indications. Knowledge of the strength of the lower segment scar would permit a selection of patients with weak scars for repeat caesarean section. This assessment cannot however be made with any certainty, neither from the history nor from the examination of the pregnant patient.

Hysterography as a means of evaluating the uterine scar was first tried by BAKER (1955). Since the appearance of his original work more than ten papers covering about 900 patients have been published. Only five materials have included non-operated patients as controls, these latter totalling 35. The findings are difficult to compile because of great variations in techniques of operation and examination, as well as in nomenclature and interpretation of the hysterographic changes.

The following changes have been described:

1. Localized protrusion in the isthmic region corresponding to the scar. This has been mentioned by all authors.

Submitted for publication 31 May 1965.

ZUSAMMENFASSUNG

Der diagnostische Wert des Pneumoperitoneums und der Beckenangiographie wurden bei gynaekologischen Fällen verglichen. Es wird hervorgehoben, dass bei Verwendung beider Methoden die Diagnose oft verbessert werden kann.

RÉSUMÉ

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Table

Cicatricial changes in hysterograms following lower transverse caesarean section compared with the findings in controls (lateral projections were only used in 23 of the controls)

	Caesarean section patients	Controls	
Projections	P a Oblique Lateral	P a	P a Lateral
Ventral protrusion — distinct	25	0	0
Ventral protrusion — indistinct	11	0	2
Lateral protrusion — distinct	19	4	1
Filling defect	6	1	2
Narrow duct like projections	2	1	0
Bending	13	0	5
Angulation	6	0	0
Total number of patients examined	48	23	23

The prognostic implications of the various roentgen findings are still unknown Correlation of the findings after caesarean section and the outcome of subsequent deliveries has so far been made only in a few cases (POIDEVIN 1959)

Technique of radiologic examinations Most authors have used iodized oil as contrast medium Water soluble contrast media (pure or with a viscous additive) have been used by a few (OBOLENSKY & ZURCHER 1963 LINDAHL & HELANDER 1959 ENDE et coll 1963) Following fluoroscopic control of the position of the cannula most authors have injected about 7 ml + 2 ml blindly during the exposures Fluoroscopic control of the filling of the uterus has been made by POLISHUK et coll (1963) It is stressed by POIDEVIN that the examination should not be carried out less than 6 months after the caesarean section but the importance of this has never been proved

Present study

Method of examination The Malmstrom vacuum cannula with a short rubber cone was applied to the external orifice The uterine cavity was filled under fluoroscopic control and the uterus gently pulled downwards to diminish ante or retroversion Contrast medium 1 to 2 ml was injected rapidly during the exposure Frontal as well as right and left oblique projections were obtained with the patient supine For the lateral projection an overcouch tube was used at a distance of one meter the central ray being directed vertically at the upper margin of the greater trochanter The contrast medium used was Urografin

2 Fistulae, evidenced by an escape of contrast medium through the scar into the parametrial or retrovesical space (POIDEVIN 1961, FOUKAS 1962, WAWIOREK 1963, DURKAN 1964)

3 Duct like projections from the region of the scar (LEPAGE et coll 1959, OBOLENSKY & ZURCHER 1963)

4 Filling defects (POIDEVIN 1961, POLISHUK et coll 1963)

5 Localized, circular dilatation in the isthmic region (BENZI & UGGERI 1962)

6 Localized, circular constriction in the isthmic region (DURKAN 1964)

7 Bending or angulation at the level of the scar (VARANGOT et coll 1959, PASETTO et coll 1962)

8 Diffuse deformity of the isthmus with irregular contours (LEPAGE et coll 1959, BENZI & UGGERI 1962, PASETTO et coll 1962, OBOLENSKY et ZURCHER 1963)

9 Dilatation and elongation of the isthmus (PASETTO et coll 1962)

Patho anatomical investigations have proved that the scar initially consists of cellular connective tissue, which later on becomes fibrous and shrinks When healing is optimal, the scar may be reduced to a delicate streak embedded in the musculature The scar is generally poorly vascularized but single larger vessels may be present (SCHWARZ et coll 1938, STIEVE 1949, SIEGEL 1952)

Relation between hysterographic and patho anatomical findings POIDEVIN & BOCKNER (1958) and LEPAGE et coll (1959) have demonstrated that the local protrusion seen roentgenographically corresponds to the scar A small protrusion corresponds to an internal excavation in the uterine wall and indicates that the scar is thinner than the surrounding parts of the wall Larger protrusions have been designated as hernia or diverticula, although their true nature has not been confirmed A fistula diagnosed by hysterography has been verified at operation by BOCKNER (1960) LEPAGE et coll found epithelialized ducts penetrating into the musculature, demonstrated in biopsy specimens from two scars They assumed that these ducts correspond to the narrow projections evident in films OBOLENSKY & ZURCHER suppose that such ducts might be caused by sutures, placed too deep

In animal experiments POIDEVIN (1961) reported endometrial inclusions deep in the musculature when all layer sutures had been used Endometriosis is mentioned by ASPLUND (1952) as a possible explanation of similar duct-like projections' found in the isthmic region of women who have been subjected to repeated abrasions Granuloma as a cause of a filling defect was demonstrated by POIDEVIN (1961) The remaining hysterographic changes have not been correlated to the morbid anatomy

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Fig 1 P a views from non operated patients Localized lateral protrusions of unknown origin




Fig 2 P a and lateral views from operated patient Localized protrusion ventrally and to both sides sharp edge ventrally

76 % All examinations were carried out during the first half of the menstrual cycle The interval between operation and examination was 2 to 5 months, except for five patients examined more than 5 months after the operation

Material The 'operated patients' have been chosen at random among those who had a lower transverse caesarean section performed during the period March 1962 to March 1963 The control group consisted of non operated patients examined for sterility From each of the two groups 8 patients have been excluded because the films were technically unsatisfactory The demands on the presentation of the cervix have increased with growing experience After these exclusions the operated group consisted of 48 and the control group of 46 patients Lateral projections were made in only 23 of the controls and oblique projections were not obtained

Results

Control patients The lateral contours of the isthmus (46 patients) were slightly irregular in half the number of controls A more marked, diffuse deformity was present in about a quarter, and more distinct localized lateral protrusions were observed in five patients (Fig 1) Lateral duct like projections were evident in one patient Two patients had central filling defects most probably due to air bubbles One patient gave the impression of having a small marginal defect that could be due to air, mucus or polypus

The ventral and dorsal contours (23 patients) were generally smooth Small prominences in the ventral contour were present in 2 patients, but no major



Fig 3 a) Lateral view from operated patient Ventral localized protrusion of rounded shape b) Oblique view from operated patient Broad based protrusion with two humps

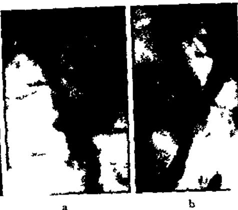


Fig 4 a) P a view from operated patient Deep saccular protrusion Fistula suspected b) Lateral view from operated patient Filling of small rounded cavity probably external to a thin scar dorsal contour concave Fistula suspected

deformities and no distinct localized protrusions in the ventral direction were observed Neither duct like projections nor filling defects were evident in the lateral views

Anteflexion and retroflexion were common observations The acuteness of the flexions depends to a large extent on the downward traction exerted and must therefore be evaluated with caution A slight bending of the isthmus with dorsal concavity not due to retroflexion was present in five patients More marked dorsal angulation was not observed Localized circular constriction or dilatation was not encountered The length and width of the contrast filled part of the isthmus cervix as it appeared in the films varied considerably Measurements were not made since in hysterography with the ordinary technique the errors would have been too great Only marked dilatation and elongation of the isthmus as a whole can be diagnosed from conventional hysterograms

Caesarean section patients Half the number of operated patients had distinct abruptly limited protrusions from the isthmus or upper part of the cervix The protrusion was typically directed ventrally and to both sides leaving the dorsal contour smooth (Fig 2) its form was usually fairly regular and rounded (Fig 3 a) A sharp, transverse ventral edge sometimes seemed to reflect the course of the scar (Fig 2) The depth and the width of the protrusion were generally of approximately the same size somewhat less than the estimated thickness of the uterine wall The form of the protrusion differed essentially



Fig 5 Fig 6

Fig 5 P a views from operated patients Narrow duct like projections resembling glands Endometriosis suspected

Fig 6 P a view (left) and lateral (right) of operated patients In left view filling defect in relation to localized protrusion granuloma suspected In right view angulation with dorsal concavity small localized protrusion at same level

from the above in 7 patients Four of these had a base about twice as broad as the depth and with two humps (Fig 3b), in one case it was very deep and saccular with a rather narrow base (Fig 4a), and in the remaining two there was a small, rounded cavity immediately ventral to a protrusion with which it was connected by a narrow stalk (Fig 4b) A small fistula may possibly have traversed the scar in the three last mentioned cases, endometrial inclusions, however, is another possibility

It could not be decided with certainty whether a cicatricial protrusion was present or not in about a quarter of the patients The majority of these had very small, diffuse irregularities of the ventral contour, the decision resting upon imagining the central contour as it would have been had the patient not been operated upon The uncertainty with which this baseline can be drawn makes it impossible to diagnose smaller cicatricial protrusions A considerable lateral protrusion without definite changes in the ventral contour was evident in one patient, the cicatricial origin of the protrusion was not certain Finally no protrusion was visible in a quarter of the operated patients

Two caesarean section patients presented narrow deep, duct like lateral projections (Fig 5), the real nature of the projections was not obvious, but they seemed to penetrate into the musculature A filling defect was present in six operated patients Four were obviously due to air bubbles the remaining two were more irregular and rather suggested space occupying processes (Fig 6, left)



Fig 7 Removed uterus from a patient who had had a lower segment transverse caesarean section a) Pa view after injection of contrast medium b) Photograph of specimen The posterior wall has been cut in the midline and the anterior wall is seen from behind c) Specimen The anterior wall has been cut in the midline and the left half is seen from the right The scar is thinner than the surrounding parts of the wall forming a groove on the inner and outer surfaces d) Lateral view after injection of contrast medium

Localized circular constriction or dilatation has not been observed in operated patients

Bending of the isthmus with dorsal concavity was about as frequent in operated patients as in the controls (Fig 4b) Dorsal angulation was observed in 6 patients in those who had a ventral protrusion as well both were situated at the same level (Fig 6 right)

No obvious dilatation or elongation of the isthmus as a whole was encountered Apart from the localized changes the isthmus cervix of the operated patients was generally normal in appearance

Relation between clinical course and hysterographic findings The present material is too small for a proper statistical evaluation A distinct cicatricial protrusion was found more frequently in women who had had more than one caesarean section and in women who had had the caesarean section performed before the onset of labour These differences may suggest correlation and call for further study

The history of patients with special hysterographic changes may be of special interest Out of 4 patients with broad based humpy protrusions three had been operated upon twice Two obviously separate protrusions have not been observed in any patient All the patients with a probable fistula or granuloma as well as those with narrow projections had an uncomplicated post operative history Conversely two patients who had had fever and one who

was anemic postoperatively presented ordinary regular protrusions of moderate size.

It may be expected that the scar will be situated lower in the cervix if the lower segment has been dilated and drawn upwards around the presenting fetal part before the operation. The authors had the impression of such a tendency but this could not be verified since exact measurement proved impracticable.

Discussion

The main purpose of this study has been to investigate the occurrence of the different hysterographic changes described in the literature. An attempt has also been made to evaluate the degree to which the changes are characteristic of caesarean section.

The control material consisted of sterile women, the majority of whom had never been pregnant. Such material might seem less suitable but according to Asplund (1952) a preceding delivery causes no important changes in the hysterographic appearances. Both materials were unsorted in order to place the cicatricial changes against the background of normal variations and common non-specific changes.

Distinct localized protrusions in the ventral direction and marked angulation seem to be specific cicatricial changes. A fistula in the isthmic region will almost certainly be caused by the operation. Lateral protrusions alone are much less specific than ventral. Even rather large protrusions are not necessarily cicatricial unless they have a distinct ventral component. Duct-like projections, filling defects, slight bending and diffuse deformity of the isthmus may be caused by the scar but may also be non-specific. Slight or atypical changes, which could not with certainty be diagnosed as cicatricial or non-cicatricial, were present in about one fourth of the patients. It is of interest to realise the existence of this group, since it may explain to some degree the different frequencies of cicatricial changes reported by different authors. For practical purposes these minor changes are probably less important.

A grading of the changes with regard to the strength of the scar can so far only be tentative. A scar with a fistula must be considered weak. A deep protrusion most probably reflects a thin scar and so also suggests weakness. This relation, however, is uncertain, and exact measurements of the depth of the protrusion must be of limited value. Endometriosis and granuloma may be signs of defective wound healing, and therefore narrow projections and filling defects should be considered of some importance. With increasing experience the evaluation of the appearances may become more conclusive. At

the present time a fistula may indicate a corrective operation or a repeat caesarean section Other marked changes may to some degree contribute to the indication for the latter These practical conclusions however, are still too uncertain to justify the routine use of this examination

Technical considerations Contrary to most investigators the authors have used a water soluble contrast medium without a viscosity increasing additive The slight distension necessary for the demonstration of detail in the cervix and isthmus is more difficult to obtain with a thin than with a viscous contrast medium With patent Fallopian tubes and retroflexion the filling can sometimes be maintained only for a short time This difficulty may be overcome by a short rapid injection at the same time as the exposure

Contrast medium in the peritoneal cavity may conceal part of the uterus Too large a spill can be avoided if the exposures are made immediately the uterine cavity has been filled Should a pool of medium have collected in the recto uterine pouch slight traction will usually make the cervix isthmus visible below it

The use of a thin contrast medium thus requires a somewhat special technique On the other hand the use of a viscous contrast medium, oily or watery implies a certain risk of local or embolic complications thus limiting endeavours to obtain optimal filling Furthermore the entrance of the medium into small irregularities in the wall and its admixture with cervical mucus may be inhibited to the same degree as its passage through the Fallopian tubes

The authors feel that the water soluble contrast medium has given quite satisfactory results The harmlessness of the substance is essential in examinations of this kind

Fluoroscopic control of the progressive filling and the position of the uterus has been found advantageous The amount of contrast medium used in the different subjects varied so much that blind injection of a standard dosage seems inexpedient Improvement in quality of films and reduction of the number of repeat exposures outweigh the hazards connected with the small dose of radiation during fluoroscopy This is particularly true when an image intensifier is used The oblique projections gave only little additional information in relation to the p a and lateral projections

SUMMARY

The hysterographic changes in 48 women who had had a transverse lower segment caesarean section performed are described and compared with the findings in 46 controls The specificity of the changes is discussed The use of water soluble contrast medium without any viscosity increasing additive as well as individual dosage and fluoroscopic control of the uterine filling are recommended

ZUSAMMENFASSUNG

Das Röntgenbild der Hysterographie nach querem Kaiserschnitt im unteren Segment wird in 48 Fällen beschrieben und mit 46 Kontrollen verglichen Es wird erörtert in wie weit das Bild typisch ist Es wird empfohlen ein wasserlösliches Kontrastmittel ohne viskösen Zusatz zu verwenden, auch die jeweils notwendige Menge und die Durchleuchtungskontrolle werden besprochen

RÉSUMÉ

Les auteurs décrivent les modifications hystérographiques chez 48 femmes après césarienne transversale du segment inférieur et les comparent aux images hystérographiques de 46 sujets témoins Ils étudient la spécificité de ces modifications Ils recommandent l emploi d un moyen de contraste hydrosoluble sans addition de produit augmentant la viscosité et le contrôle radioscopique du remplissage de l utérus

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INSTRUMENT FOR MEASURING ANGLES FROM ROENTGENOGRAMS

by

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An angle in the body as depicted in roentgenograms is almost invariably distorted The angle can be measured directly on the film only when the latter has been obtained parallel to the plane of the angle In theory, an angle represented by two projections may be determined if the angle between the projections is known, this can be measured trigonometrically or graphically in a number of ways, although either procedure is too complicated for routine use

An instrument by means of which the projected angle can be obtained graphically will now be described The method is a general one insofar as the directions of projection need not be perpendicular to each other nor need there be right angles between the beam and the film or between the beam and either side of the angle

Geometry A coordinate system consisting of three axes having the apex of the required angle as origin is inserted (Fig 1) Two of these axes are designated the first and second zero rays, from the first and second ray source, respectively The third axis, perpendicular to the two zero rays, is referred to as the central axis Through each zero ray, a bundle of planes, all of which form different angles with the central axis, are inserted (Fig 2), these planes are referred to below as bundle planes Each plane of a bundle is identified

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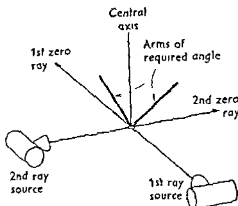


Fig 1 The coordinate system

by a coordinate denoting its angle to the central axis and a subscript denoting whether the plane belongs to the first or second bundle By means of this system the direction of any line from the origin may be defined in terms of the two coordinates of the two bundle planes to which the line belongs

Each bundle contains one plane that is perpendicular to the central axis These two planes, 90_1 and 90 are coincident and form the zero plane (Fig 3), which intersects each film in one line the first and second zero lines in the respective films I and II The perpendiculars to the respective zero lines in the planes of the films are designated the first and second zero normal (Fig 4) The zero line in film I may be considered as the projection of the second zero ray from the first source and the zero line in film II as the projection of the first zero ray from the second source The zero lines can usually be constructed on the two films from the information contained in them even if the orientations of the films in relation to the coordinate system are unknown (Fig 5)

For the coordinate system to be used graphically it must be reproduced on a surface and it is convenient to employ the intersection of the coordinate system with the surface of a sphere the centre of which coincides with the origin of the system (Fig 6) The *intersection* of a bundle plane with this surface is a great circle and the two bundles give two bundles of great circles — two systems of meridians — the axes of which are the two zero rays

Description of the instrument

The instrument which consists of three disks that can be rotated about a short common axis may be considered as a two dimensional model of the sphere in question viewed in the direction of the central axis This axis is then

Film I
Central axis
0°
45°
45°
90°
90°
2nd zero ray
1st zero ray

Fig 2 Some of the planes in the bundle through the first zero ray

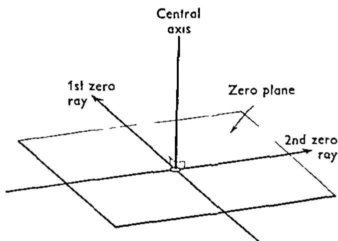


Fig 3 The zero plane

represented by the axis of the instrument, and each of the two meridian systems by a system of ellipses in the instrument

The bottom disk is made of a rigid white and opaque plastic and is inscribed with a system of meridians and latitudes identical with an orthographic projection of a terrestrial globe the interval between the lines is 5° A scale marked in degrees lies along the periphery of the 'northern hemisphere of this system This disk is referred to as the lower meridian disk The middle disk the upper meridian disk, is of a rigid transparent material and bears a meridian system with an equator The uppermost disk, the plotting disk' is disposable and composed of a cheap transparent material The geometric construction is performed on the latter by plotting points obtained from the two meridian disks If the disk is of transparent paper the plotting can be done with a pencil, if it is of a transparent plastic material small pieces of transparent adhesive tape marked with small points are affixed and can be used repeatedly

The two meridian systems may be set in relation to one another at the angle between the zero rays by rotating the two lower disks The instrument then constitutes a model of the coordinate system described above The bundle planes through the first zero ray are represented by the meridians on the lower disk and the bundle planes through the second zero ray by the meridians on the upper disk The meridians and latitudes are labelled according to their angular distance from the central axis the lower meridians take subscript 1 and the upper meridians subscript 2 As viewed from the ray source the meridians to the right of the central axis are denoted as positive those to the left as negative The latitudes within the northern hemisphere of the lower disk are regarded as negative and those outside as positive

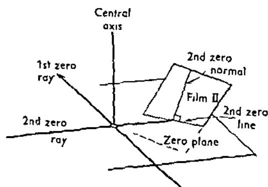


Fig 4 The zero line and the zero normal in film II

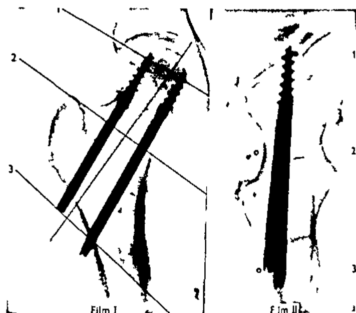


Fig. 9. Method for locating the zero lines. Superimposed details in the right roentgenogram were projected by the same beam. Ray 1 touched the top of the two screws; ray 2 passed tangential to the trochanter major and passed trochanter minor at a certain distance and ray 3 touched the head of the first screw and passed the other one a centimeter from its head. These three pairs of details are well shown in the roentgenogram of film I and lines can be drawn *to represent the directions of the* rays that projected the roentgenogram in film II.

Applications

The measurement of an angle with the instrument consists of two operations. In the first, the directions of the sides of the angle are represented as two points on the plotting disk. This is done by measuring on each film the angles between the zero normal and the images of the two sides. This will give four angles denoting the four bundle planes to which the sides belong, i.e. each side to two planes, one to each film. The meridian disks having been set in relation to one another at the angle between the zero rays, the two meridians that represent the angles read off for one of the sides are found. Their point of intersection, representing the direction of the side, is marked on the plotting disk. The other side is likewise represented by a point. The two points together represent the angle on the plotting disk.

The second operation consists in measuring the angular distance between the two points. This is done by rotating the plotting disk so that the two points fall on one and the same lower meridian. The difference in latitude between the two points is the angle required.

Example 1 (Fig. 10). Consider the special case in which the two films are perpendicular to the zero rays. Let the film depict the required angle having sides A and B, and draw the zero normals on the films and measure the angles they make with the images of the sides. Let the image of A form angle α_1 in film I and angle α_2 in film II with their respective zero normals, and let the corresponding angles for the images of B be β_1 and B_2. Rotate one meridian disk until the axes of the meridian systems intersect at the angle between the two zero rays. Mark on the plotting disk the point of intersection between lower meridian α_1 and

Fig 6 Intersection between the bundle planes through the first zero ray and the sphere whose centre coincides with the origin of the system

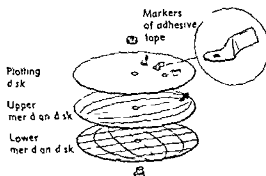


Fig 7 Exploded view of the instrument



Fig 8 Components of the instrument

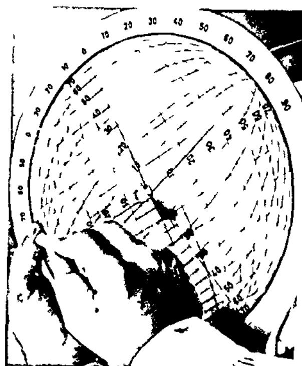


Fig. 9. The instrument in use.

upper meridian α; this point represents the direction of side A. Similarly, mark the point representing the direction of side B, i.e. the intersection of meridians β_1 and β_2. The directions of the two sides of the angle being defined by the two points, the first operation is now complete.

The second operation, consisting in the measurement of the angular distance between the two points, is performed by rotating the plotting disk so that the two points fall on one lower meridian. The difference in latitude between the points in this position is the angle required. If found easier, the two points may be moved parallel to the latitudes out to the periphery, after which the plotting disk is rotated until one of the points coincides with the zero of the scale; at the other point the value of the required angle may be read off on the scale.

By representing a number of lines simultaneously on the plotting disk the angle between any pair of them can be obtained.

Example 2. Schematic drawings of a fracture of the femoral neck in a.p. and lateral projections are shown in Fig. 10. The films are again perpendicular to the respective zero rays. An arrow in the a.p. view indicates the direction of the zero ray used for the lateral view, and the zero ray used for the frontal view is indicated in the same way in the lateral view. The zero normal is drawn on the two films, followed by the axes of the shaft, the neck and head of the femur and the line connecting the centre of the head and the fovea. The angles that each of these lines forms with the zero normal are measured on both films. The following values were obtained:

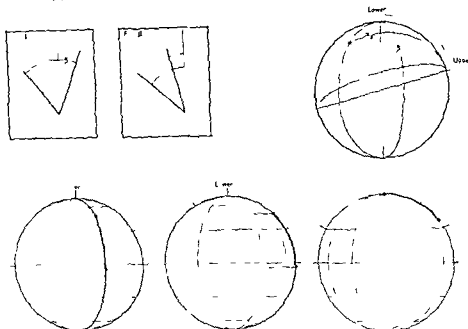


Fig. 10. Illustration of application of the instrument. *Top left*: the two films with axes and zero normals. *Top right*: The two meridian systems have been set at the angle between the zero rays; the meridians having the angles formed by the axes with the zero normals intersect at the two points *a* and *b*; these are marked on the plotting disk. *Bottom left*: The plotting disk is rotated so that points *a* and *b* lie on one and the same meridian in the lower system. *Bottom middle*: The two points are translated to the periphery. *Bottom right*: The plotting disk is again rotated until *a* coincides with the zero of the scale. The value of the required angle can now be read off at *b*.

Angles between the zero normal and	A.p. view (degrees)	Lateral view (degrees)
Axis of shaft of femur	−44	−10
Axis of neck	+ 8	+15
Axis of head	−11	−16
Line between centre of head and fovea	+ 7	18

The a.p. and lateral projections are represented by the lower and upper meridian disks respectively, which are set at the angles between the two zero rays (80° in this case). The four points that represent the directions of the four lines are marked on the plotting disk by using the meridians corresponding to the measured angles. The angles between any two of the four lines can now be obtained by rotating the plotting disk so that the two corresponding points lie on the same lower meridian, as shown on p. 164.

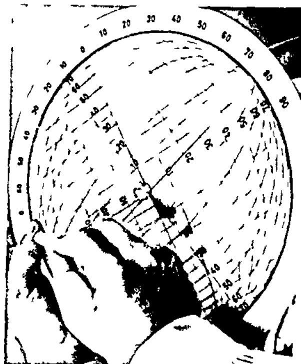


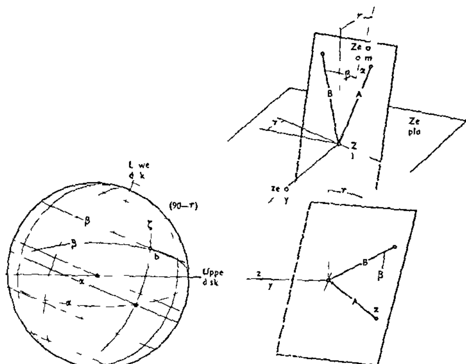
Fig 9 The instrument in use

upper meridian α_1 this point represents the direction of side A Similarly mark the point representing the direction of side B i e the intersection of meridians β_1 and β_2 The directions of the two sides of the angle being defined by the two points the first operation is now complete

The second operation consisting in the measurement of the angular distance between the two points is performed by rotating the plotting disk so that the two points fall on one lower meridian The difference in latitude between the points in this position is the angle required If found easier the two points may be moved parallel to the latitudes out to the periphery after which the plotting disk is rotated until one of the points coincides with the zero of the scale at the other point the value of the required angle may be read off on the scale

By representing a number of lines simultaneously on the plotting disk the angle between any pair of them can be obtained

Example 2 Schematic drawings of a fracture of the femoral neck in a p and lateral projections are shown in Fig 10 The films are again perpendicular to the respective zero rays An arrow in the a p view indicates the direction of the zero ray used for the lateral view and the zero ray used for the frontal view is indicated in the same way in the lateral view The zero normal is drawn on the two films followed by the axes of the shaft the neck and head of the femur and the line connecting the centre of the head and the fovea The angles that each of these lines forms with the zero normal are measured on both films The following values were obtained



F g 1 Method of finding the merid ans for the required angle when the film is not perpendicular to the ero r y *Left* Us ng the instrument fo finding the requ red merid ans α and β′ *R ght* F lm and ero pl ne obl que v ew (top) and seen from abo e (bottom) The or entat on of the film is defined by angles and η S des A and B *n the film* form a gles α and β w th the zero nor mal

angle $(90-\eta)$ The lower meridian representing the angle ζ with the central axis is then chosen This meridian has *now the same* orientation to the upper meridian system as the film to the bundle of planes *in* the coordinate system The zero normal in the film is represented by the point of intersection of the lower meridian with latitude 0 *The intersection* of meridian ζ and a latitude represents the direction in the film of a line making the same angle with the zero normal as that of the latitude *The* directions of the sides of the angle in the film are then represented by the points of intersection between the meridian and the two latitudes whose *values are* the respective angles between the zero normal and the images of the two sides We then on the instrument have two points representing the directions of the images of the sides forming the angle on the film The required bundle planes *have* the same value as those

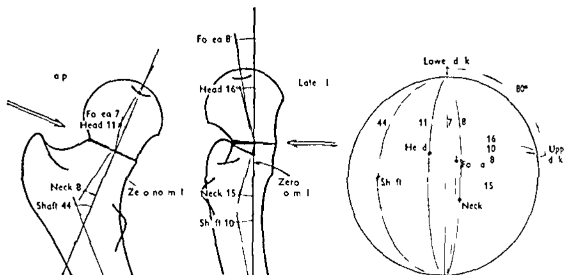


Fig 11 Simultaneous plotting of the directions of several lines *Left* The two radiographic projections with axes and zero normals plotted *Right* The directions of the four axes represented on the plotting disk The angle between any pair may easily be read off

Angles between

Axes of femoral shaft and neck	53
Axes of femoral neck and head	34
Axes of femoral shaft and head	35
Axis of head and line between centre of head and fovea	19

Other uses of the instrument The films in the above two examples were assumed to be perpendicular to the zero rays Only in this special case is it possible to measure the meridian angles for the sides of the required angle directly on the films The orientation of the films is generally arbitrary, but the meridians are readily found provided the relation between the film, the central axis and the zero ray during the exposure is known The procedure is as follows for both films (Fig 12) The zero normal is drawn on the film in the usual way and the angles between this normal and the images of the sides of the angle are measured The orientation of the plane of the film may be defined by two angles ζ between the central axis and the zero normal, and η between the zero line and the normal to the zero ray in the zero plane

The instrument is then used in the following way The upper meridian system is taken to represent the bundle of planes to the film and one lower meridian will be found that represents the orientation of this film This necessitates the two disks being so set that the axes of the meridians intersect at the

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ROENTGENOLOGIC SOFT TISSUE APPEARANCES IN HIP JOINT DISEASE

by

SVEN REICHMANN

Roentgenologic soft tissue changes in the region of bones and joints in acute suppurative osteomyelitis have been described by LAURELL (1927) and by BAYLIN & GLENN (1947) These authors noticed that the junction between the subcutaneous fat tissue and the underlying muscles grew indistinct, and that irregular streaks appeared in the subcutis They reported a swelling of the muscles in the deeper tissues and a blurring of the fat containing intermuscular septa changes that were considered to be caused by oedematous infiltration and by dilatation of the vessels BAYLIN & GLENN mentioned other conditions such as soft tissue tumours generalized oedema and hematoma which may produce similar roentgenologic signs

Four fatty layers are evident around the hip joint in the a p projection One of these lying in the pelvis was described by HEFKE & TURNER (1942) as being medial to the obturator internus muscle The other fatty layers are situated outside the pelvis around the femoral neck (Figs 1, 6a and 7) Two of them appear to extend from the iliac bone down to the greater trochanter,

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upper meridians that now pass through these points, they are read off and recorded. The bundle planes containing the sides of the angle are found in the same way for the other film. The subsequent procedure is then as described in the case in which the films are perpendicular to the zero rays.

With the instrument now described it is possible not only to measure angles between two lines but also *angles between one line and a plane, or between two planes*. A more detailed description of the instrument and its use has been published in the Supplement series of this journal (EDHOLM 1966).

The instrument described in this article may be obtained from AB Kifa, Solna 1, Sweden.

SUMMARY

A short description is given of an instrument designed for graphical measurement of an angle from its two radiographic projections. Angles between two lines, between a line and a plane, or between two planes can also be measured, and the projecting beams need not be perpendicular to each other or to the films.

ZUSAMMENFASSUNG

Eine kurze Beschreibung eines Instrumentes zur graphischen Messung eines Winkels aus zwei radiographischen Projektionen wird gegeben. Es können auch Winkeln zwischen zwei Linien, zwischen einer Linie und einer Fläche oder zwischen zwei Flächen gemessen werden, wobei die projizierenden Strahlen nicht rechtwinklig zueinander oder zum Film zu sein brauchen.

RÉSUMÉ

Brève description d'un instrument destiné à la mesure graphique d'un angle par deux projections radiographiques. Il permet de mesurer l'angle formé par deux lignes, une ligne et un plan, ou deux plans; il n'est pas nécessaire que les rayonnements projetants soient perpendiculaires entre eux ou aux plans.

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FROM DEPARTMENT OF ROENTGENOLOGY III (DIRECTOR ASSOC PROF OSBORNE BARTLEY) SAHLGRENSKA SJUKHUSET AND THE DEPARTMENT OF ANATOMY (DIRECTOR PROF BO E INGELMARK) UNIVERSITY OF GOTHENBURG SWEDEN

ROENTGENOLOGIC SOFT TISSUE APPEARANCES IN HIP JOINT DISEASE

by

SVEN REICHMANN

Roentgenologic soft tissue changes in the region of bones and joints in acute suppurative osteomyelitis have been described by LAURELL (1927) and by BAYLIN & GLENN (1947) These authors noticed that the junction between the subcutaneous fat tissue and the underlying muscles grew indistinct, and that irregular streaks appeared in the subcutis They reported a swelling of the muscles in the deeper tissues and a blurring of the fat containing intermuscular septa changes that were considered to be caused by oedematous infiltration and by dilatation of the vessels BAYLIN & GLENN mentioned other conditions such as soft tissue tumours generalized oedema and hematoma which may produce similar roentgenologic signs

Four fatty layers are evident around the hip joint in the a p projection One of these lying in the pelvis was described by HEFKE & TURNER (1942) as being medial to the obturator internus muscle The other fatty layers are situated outside the pelvis around the femoral neck (Figs 1 6a and 7) Two of them appear to extend from the iliac bone down to the greater trochanter

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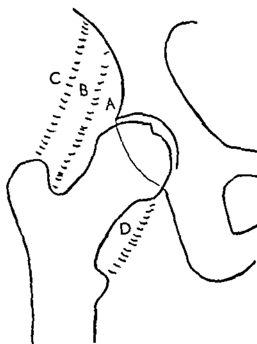


Fig. 1. Schematic drawing of the hip joint. Letters denote soft tissues between fatty layers (striated). (Cf. figs 6 a and 7 and Table 1.)

while the third is situated medial to the hip joint with its caudal end at the level of the lesser trochanter. The roentgen appearances of these three extrapelvic fatty layers have been discussed by LANGE (1927) and by DREY (1953), their partly contradictory views are summarised below.

Soft tissue	LANGE	DREY
A	Joint capsule	M. gluteus minimus
B	M. gluteus minimus	M. gluteus medius
C	M. gluteus medius	—
D	M. iliopsoas	M. iliopsoas

The periarticular soft tissues of the hip joint have been studied in routine roentgenograms by several authors. Swelling of the muscles and blurring of the fatty layers have been reported by JORUP & KJELLBERG (1948) in acute suppurative coxitis in infants. The roentgen signs of post operative coxitis have been studied in 21 cases by BARTLEY & CHIDEKEL (1966), the first of these always being blurring of the fatty layers lateral to the hip joint. Displacement of the fatty layer lying immediately lateral to the hip has been evident in hip joint diseases such as tuberculous coxitis and transient synovitis (LANGE 1927, LOCRÒSCINO 1936, MARTIN 1951, HERMEL & SKLAROFF 1954, HERMEL & ALBERT 1962, WHITE 1962); this displacement has been supposed to depend on capsular swelling. Displacements of the intrapelvic and of the medial of the

extrapelvic fatty layers have been described by HEFKE & TURNER (1942) and DREY (1953) They generally observed no blurring of the fat but still considered the cause to be an oedematous swelling of the soft tissues

The present investigation was performed to determine (1) the muscles between which the extrapelvic fatty layers are situated, (b) the topographic relations between the fatty layers and the capsule of the hip joint (c) whether it is possible for a capsular swelling to give rise to a roentgenologically visible displacement of one or more of the fatty layers and (d) whether it is possible that one or more of the fatty layers may be affected early in the development of a periarticular oedema

The intrapelvic fatty layer was not studied as it is considered to be of less importance than the extrapelvic layers in diseases of the hip joint

Materials and Methods The topographic anatomy was investigated at autopsy in two adults and one newborn infant In addition 17 living subjects were studied roentgenologically Comparison was made between a conventional roentgenogram and a series of tomograms identically centered in two of these patients The influence of the projection on the position of the fatty layers in the films was studied in the remaining 15 patients

Autolysis had not progressed so far that any difficulty arose in the identification of the anatomic structures in any of the autopsy cases Only cases without obvious pathologic conditions in or around the hip joints were studied

A roentgenologic identification of the fatty layers was included in the first of the dissections An a p roentgenogram having been obtained hypodermic needles were introduced into the fatty layers and their positions verified by means of stereoscopic films taken at about 20 A contrast medium, made polymerizable for preventing it floating during the dissections and containing barium sulfate gelatine in high concentration and formalin was made ex tempore the mix becomes highly viscous in 15 minutes This was injected through the hypodermic needles which were then withdrawn the sites of the contrast medium were verified by stereoroentgenograms (Fig 2 a)

The dissections were performed in the same way in all three cases The incisions were made perpendicular to the fatty layers, and when they were reached the surrounding muscles were identified The field of dissection was then increased so that the relations between the fatty layers and the joint capsule could be determined The results were registered in series of stereoscopic colour photographs

The tomographic studies were performed in a female and a male subject 37 and 55 years old respectively The roentgen films of the man revealed minor osteoarthritic changes while the woman had no evidence of hip joint disease

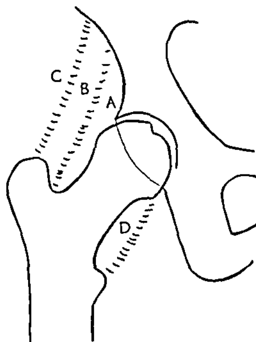


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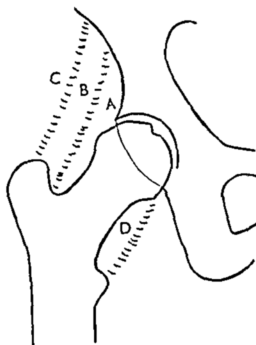


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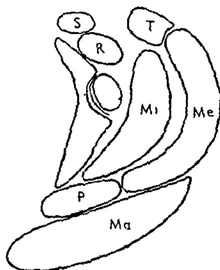


Fig 3 Schematic drawing of transverse plane through hip and muscles cranial and lateral to it Fatty tissue lies between the muscles

S — m sartorius
R — m rectus femoris
T — m tensor fasciae latae
Mi — m gluteus minimus
Me — m gluteus medius
P — m piriformis
Ma — m gluteus maximus

of the external layer was situated at the level of the hip joint while the internal layer was widest in its anterior intermuscular part The gluteus maximus muscle lay behind the glutei medius and minimus muscles with no fatty layer in front of it

The fatty layer situated medial to the hip was identified along the medial border of the iliopsoas muscle (Fig 4) It communicated ventrocranially with the fat in the femoral triangle and dorsocranially reached the hip joint capsule in its ventromedial part where it was inserted into the margin of the acetabulum The width of the layer in its distal part decreased down to the lesser trochanter the width of the rest of the layer was constant

The tomographic series of the male is illustrated in Fig 5 None of the fatty layers could be traced further back than to a frontal plane through the lesser trochanter The external of the lateral layers disappeared ventrally at the level of the anterior surface of the femur its density being maximal in a plane through the centre of the femoral head its orientation was mainly sagittal The internal of the lateral layers in the conventional roentgenogram was bounded medially by the relatively broad soft tissue marked A in Fig 1 The width of this tissue was much less in the tomogram through the centre of the femoral head roughly corresponding to the thickness of the joint capsule, the contrast of this layer was rather low The layer had a more lateral position and a higher contrast in the tomograms through the soft tissues in front of the joint the appearances resembling those evident in the conventional roentgenogram The fatty layer in the latter was limited medially only by the muscles situated in



a



b

Fig. 2. Autopsy case. a) One of a set of stereoscopic films showing contrast medium in the two lateral fatty layers. b) View from ventral and caudal aspects. The m. gluteus minimus (→) lies between spots of contrast medium. Other muscles are m. gluteus medius (○→), m. tensor fasciae latae (→), m. sartorius (↦→) and m. rectus femoris (⟶).

With the same centering, an ordinary a.p. roentgenogram and a series of linear tomograms were obtained. 1 cm cuts were taken from the inguinal subcutis backwards until none of the layers could be distinguished.

The influence of the projection was studied in 15 instances in frontal films taken at about 10° from the lateral and medial aspects.

Results

The appearances were the same in the three autopsy cases.

The topographic relations for the two fatty layers situated lateral to the hip are shown in Figs 2b and 3. The external of these lateral layers lay between the glutei medius and minimus muscles. In front of the latter muscle there was a communication with the internal layer, which began ventrally between the rectus femoris and tensor fasciae latae muscles. The fatty layer was continued backwards from its intermuscular part into a pericapsular part between the medial aspect of the gluteus minimus muscle and the upper lateral part of the hip joint capsule. These fatty layers grew thinner dorsally. The maximal width

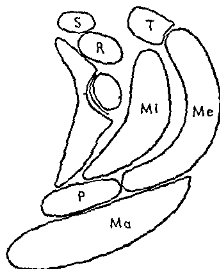


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The fatty layer situated medial to the hip was identified along the medial border of the iliopsoas muscle (Fig 4) It communicated ventrocranially with the fat in the femoral triangle and dorsocranially reached the hip joint capsule in its ventromedial part where it was inserted into the margin of the acetabulum The width of the layer in its distal part decreased down to the lesser trochanter the width of the rest of the layer was *constant*

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The appearances were the same in the three autopsy cases.

The topographic relations for the two fatty layers situated lateral to the hip are shown in Figs 2b and 3. The external of these lateral layers lay between the glutei medius and minimus muscles. In front of the latter muscle there was a communication with the internal layer, which began ventrally between the rectus femoris and tensor fasciae latae muscles. The fatty layer was continued backwards from its intermuscular part into a pericapsular part between the medial aspect of the gluteus minimus muscle and the upper lateral part of the hip joint capsule. These fatty layers grew thinner dorsally. The maximal width

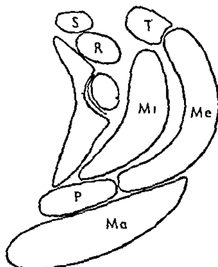


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Fig 4 Autopsy case viewed from ventromedial and caudal aspects Contrast medium in the fatty layer situated medially to the m iliopsoas (→) the a femoralis lies ventrally (→→)

front of the hip The medial fatty layer could be judged only where it was not projected over bone, from the lesser trochanter it extended ventrocranially as its sagittal depth increased The tomographic series from the female differed in one respect from that of the male The soft tissue in the conventional roentgenogram (Fig 6) was much narrower, and the tomograms disclosed that the internal of the lateral layers was more sagittally oriented The fatty layer in the conventional roentgenogram was limited medially both by the muscles in front of the joint and by the joint capsule

The 15 patients were examined in different projections and it was observed that the internal of the lateral layers was displaced in a way suggesting that at least a large part of it was situated in front of the hip No such obvious displacement of the other fatty layers was noticed

Discussion

While neither LANGE (1927) nor DREY (1953) based their conclusions on morphologic investigations of their own they were nevertheless correct with respect to the medial layer The views of DREY regarding the lateral layers have not been confirmed by this investigation LANGE was of the opinion that the



Fig 5 Con ention l roentgenogram (a) and tomograms th ough the centre of the femoral he d (b) and through th t sues n front of the h p (c) in a man aged 5J The f tty layer (arrows) in (a) is situated in front of the jo nt

internal of the lateral layers in the whole of its extension comes into contact with the joint capsule This is true however only of its dorsal part

Two conditions must be fulfilled for the roentgen diagnosis of a capsular swelling part of the capsule must be visible with certainty in the roentgeno gram and this part must be capable of being displaced by an excess of intra articular fluid

The dorsal part of the internal of the lateral fatty layers lies close to the upper lateral part of the joint capsule in such a way that a capsular swelling would cause its displacement perpendicular to the roentgen beam However the major part or even all of the fatty layer as seen in a frontal roentgenogram consists of the ventral part which has no intimate relation to the capsule Due to anatomi cal conditions it is impossible to identify the capsular contour with certainty even in special projections (Fig 3)

Any specialised technique e g a tomographic one, for identifying the capsule has not been sought since it seems improbable that its upper part can be dis placed by an excess of intraarticular fluid Very thick and strong ligaments are reinforcing the capsule in this region while the caudal and dorsal parts are much thinner and more yielding (Fick 1904) When the patient is positioned for an a p roentgenogram the upper part of the capsule is streched and pressed against the femoral neck obliterating the underlying joint space This phenomenon is well known from the normal arthrogram of the hip joint Thus



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cular reflex which, when unrestrained, produces such an orientation of the joint that its volume becomes maximal This is achieved by a moderate degree of flexion together with some outward rotation and abduction Contraction exceeding the normal muscular tone may therefore occur in the rectus femoris iliopsoas and obturator internus muscles causing a displacement of the fatty layers

As mentioned periarticular oedema has been demonstrated roentgenologically *both in infants and adults with suppurative coxitis* This swelling may in the former be so extensive as to produce a demonstrable increase in the circumference of the thigh (HOWARD 1957, WHITE 1962) The present investigation has disclosed that the medial and internal of the lateral layers come into contact with the capsule, there is also a communication between the lateral layers It is therefore probable in view of the anatomical relations that pericapsular oedema in coxitis will spread early in the loose fatty tissue, giving rise to blurring of the fatty layers

SUMMARY

The anatomy and relations of the three extrapelvic fatty layers to the joint capsule of the hip joint were studied Two of the layers come into contact with the capsule which makes the early demonstration of periarticular oedema in septic coxitis possible The capsule contours on the other hand cannot be studied in a conventional a p roentgenogram so that it is impossible to make an accurate diagnosis of swelling of the capsule with this technique

ZUSAMMENFASSUNG

Die Anatomie und die Lagebeziehungen der drei extrapelvischen Fettschichten zu der Gelenkskapsel des Huftgelenkes wurden untersucht Zwei der Fettschichten treten in enge Beziehung mit der Gelenkkapsel eine Tatsache die die fruhzeitige Darstellung eines Ödems bei septischer Coxitis ermoglicht Leider konnen die genauen Konturen der Kapsel in dem gewohnlichen a p Rontgenbild nicht dargestellt werden so dass es nicht moglich ist eine genaue Diagnose einer Kapselschwellung mit dieser Technik zu stellen

RÉSUMÉ

L auteur a étudié l anatomie et les rapports de trois couches graisseuses extrapelviennes avec la capsule de l articulation de la hanche Deux de ces couches entrent en contact avec la capsule ce qui permet le diagnostic précoce de l oedeme périarticulaire dans les coxites infectieuses Mais les contours de la capsule ne peuvent être étudies sur une radiographie de face ordinaire de sorte qu il est impossible de faire un diagnostic précis de gonflement de la capsule par cette technique



Fig 6 Roentgenogram in woman aged 37 The soft tissue (arrows) is much narrower than in the case represented in fig 5

of the two conditions postulated the first is certainly not present in a conventional roentgenogram and the other probably not in standard positioning For these reasons a reliable demonstration of a capsular swelling is probably not possible at present with current techniques of examination The difficulty in diagnosing a capsular swelling has also been pointed out by clinical investigators using various methods (ROSENBERG & SMITH 1956, SPOCK 1959, HERMEL & ALBERT 1962, ARCOMANO et coll 1963)

Some of the illustrations published by earlier investigators undoubtedly give the impression of a displacement of a fatty layer, mostly the internal of the lateral layers The following explanations may be considered (a) differences in projection at different examinations (b) differences in muscular thickness, (c) oedematous muscular swelling, and (d) differences in muscular contraction

The effect of different projections and the varying width of the soft tissue have already been discussed LANGE (1927) published a case of presumed regressed displacement which in reality must have been the consequence of muscular atrophy caused by immobilisation A displacement without blurring probably cannot be caused by periarticular oedema as there is good reason to believe that oedema would affect the much looser fatty tissue before the muscles An increased degree of muscular contraction may be elicited if a distended joint is forced into the position of extension and inward rotation which is required for a frontal roentgenogram The mechanism is a neuromus-

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SWEDEN

ANASTOMOSES BETWEEN EXTRACARDIAC VESSELS AND CORONARY ARTERIES — I — VIA BRONCHIAL ARTERIES

Post mortem angiographic study in adults and newborn infants

by

ANDERS MOBERG

Ischaemic heart disease is to day one of the major health problems in western countries Of all the smaller blood vessels of the body scarcely any are more essential for life than the coronary arteries These arteries were once considered to be end arteries but in 1938 SCHLESINGER showed the existence of intercoronary anastomoses He proposed that these developed where and when needed Later however LAURIE & WOODS (1958) and FULTON (1963) found that anastomoses are also present in healthy hearts from both infants and adults Study of the intracardial coronary anastomoses which nowadays can be demonstrated by coronary angiography in living subjects (PAULIN 1964) has expanded our knowledge and understanding of the pathogenesis of ischaemic heart disease and myocardial infarction

An intimation of the importance of extracardial anastomoses emerged from the report by LEARY & WEARN (1928) who described two patients with total occlusion of the two coronary ostia The occlusions were long standing

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Table 1

Age and percentage of intact lumen of coronary arteries (mean values)

Age (yrs)	Sex and number of cases		Percentage of intact lumen of coronary artery*		
	Males (18)	Females (19)	Right	Left descending	Left circumflex
11—20		1	53	43	58
21—30		1	26	19	29
31—40	1		52	45	43
41—50		1	16	8	14
51—60	5	8 (2)	32 (30)	27 (28)	33 (20)
61—70	4 (1)	3	34 (25)	32 (17)	33 (35)
71—80	7	4 (3)	28 (27)	18 (15)	22 (20)
81—90	1	1	28	16	28

Since it was desired to estimate the degree of stenosis transverse sections of the arteries must be used In atheromatosis the internal elastic lamina can be destroyed or changes can be present in the media. It was therefore necessary to use the external elastic lamina as the reference This means that the expression the degree of stenosis also includes the cross-section area of the media The method therefore gave low values i e values apparently expressing higher degrees of stenosis than was actually the case The results however agree with those published by LOBER (1953)

* Figures in parantheses indicate the six subjects mentioned in the discussion in which only minor atrial arteries were filled All the other subjects had anastomoses to the ventricular area (cf table 4)

Like most mediastinal structures the posterior part of the pericardium is supplied by the bronchial arteries These arteries arise from the upper part of the descending aorta at a level ranging from the third to the eighth thoracic vertebrae (CAULDWELL et coll 1948 GIORDANI & PINNA 1956) There is always at least one right and one left bronchial artery and in a series of 150 dissected human cadavers CAULDWELL et coll found six with as many as five arteries In their survey they found that in 133 subjects a right bronchial artery arose in common with an aortic intercostal artery (Fig 1) Before entering the lungs the bronchial arteries give off branches to adjacent structures e g hilar lymph nodes oesophagus vagus nerves (CUDKOWICZ & ARMSTRONG 1951) and the pericardium With regard to an extracardiac blood supply to the myocardium the bronchial arteries are thus in close proximity with the crucial area the pericardial reflexion From this region the pathway down to the main coronary arteries at the ventricular level would be via the atrial arteries (Fig 2)

The largest atrial artery is the sinus node artery ramus ostii cavae superioris (JAMES 1961) In about 55 per cent of subjects the artery arises from the right coronary artery ascends along the anterior part of the right atrium up to the

the patients had *no previous clinical signs referable to the heart*, and at post mortem examination the myocardium had a normal appearance. The authors proposed that extracardial anastomoses must have been a major source of the myocardial blood supply.

The natural existence of extracardial anastomoses, however, seems never to have been fully analysed, although von HALLER demonstrated anastomoses between the coronary arteries and mediastinal vessels as early as 1803. In post mortem studies, HUDSON, MORITZ & WEARN (1932) injected India ink with a pressure of 220 mm Hg into the coronary arteries of 31 human subjects. They found anastomoses between the coronary arteries and the anterior mediastinal, pericardial, bronchial, superior and inferior phrenic, intercostal and oesophageal branches of the aorta. The authors stated that the extracardial anastomoses increased in number with age, but the increase was not considered in relation to the degree of coronary atheromatosis. Apart from this investigation, extracardial anastomoses in human beings have been mentioned only briefly in different reports, e.g. KOCH (1909), SCHOENMACKERS & VIETEN (1954), FULTON (1963). The anastomoses seem to have been found accidentally during investigation of other, but related, problems. In 1961, JAMES therefore stated that among the unsettled questions in the anatomy of the coronary arteries 'the extent of ... (extracardial anastomoses) ... should be investigated further ...'.

The purpose of this study was to find out the extent of extracardial anastomoses via the bronchial arteries in healthy human hearts and in hearts with pathological features. This work is part of a larger study, and subsequent papers will deal with anastomoses from the internal mammary artery and microangiographic studies of the anastomoses.

Anatomical background. Since, normally, pericardial adhesions are not present, the only possibility for a blood supply from extracardial sources to the heart would be via the pericardial reflexion. This is located posteriorly to the heart between the aorta, the superior and inferior venae cavae and the pulmonary veins.

The vasa vasorum of the aorta run in the adventitia and outer two thirds of the aortic media and thus pass through the pericardial reflexion. The arteries give branches to the epicardial and periaortic fat pads which also have a blood supply from the coronary arteries (ROBERTSON 1930/31). The vasa vasorum of the ascending aorta can also originate from the coronary ostia and terminal branches of the left coronary artery (CLARKE 1965). Thus the two vascular systems, the vasa vasorum and the coronary arteries, are a potential source of anastomoses between the systemic and the coronary arteries.

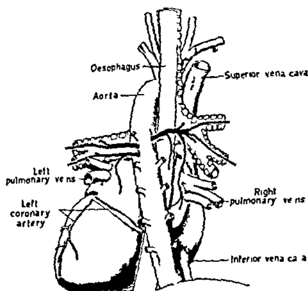


Fig 1 *Semischematic drawing dorsal view demonstrating the* close relation between the bronchial arteries (black) and the heart (For the sake of simplicity the pericardium is not shown)

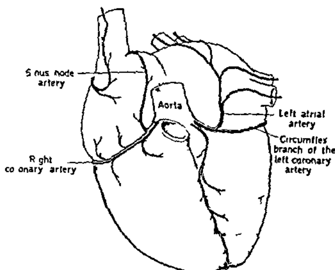


Fig 2 Semischematic drawing of the ventricular and atrial arteries of the heart As in most hearts (55) the sinus node artery arises from the right coronary artery In this series the three left atrial arteries were difficult to distinguish from each other and the arteries have therefore been jointly designated as one artery

Table 2

Heart weights and myocardial changes

Weight	Recent infarction	Recent and old infarcts	Old infarcts	Scattered fibrosis	Myocardium without major changes	Total
—300					5 (1)	5 (1)
300—399	2			1	13 (2)*	16 (2)
400—499	3			1 (1)	5 (1)	9 (2)
500—	1	1	1	1	3 (1)	7 (1)
Total	6	1	1	3 (1)	26 (5)	37 (6)

* Figures in parentheses indicate the six subjects mentioned in the discussion in which only minor atrial arteries were filled, all the other subjects had anastomoses to the ventricular area (cf. table 4)

superior vena cava which it encircles to supply the sinus node. In the remaining 45 per cent, the artery arises from the first centimetre(s) of the left circumflex artery and has a fairly similar course, ending by encircling the superior vena cava and supplying the sinus node.

All other atrial arteries are small, vary in number and location, and none has a size comparable to that of the sinus node artery. In SPALTEHOLZ's original description (1924), all the right and left atrial arteries, including the sinus node artery, were designated as the anterior, intermediate or posterior, depending upon their origin. JAMES & BURCH (1958) found that all hearts did not have the full complement of atrial arteries. The general course of these small arteries is from a ventricular coronary artery towards the superior parts of the atria. The arteries arborize over the atrial walls and reach the region of the pericardial reflexion at the vein inlets.

The atrial arteries anastomose freely — especially with the sinus node artery — and their importance as potential intracardial anastomoses has often been stressed (JAMES & BURCH 1958, FULTON 1963).

Material and Methods

Adults. The investigation was carried out on autopsy specimens and the interval between death and autopsy ranged from 7 hours to 4 days, during which period the bodies were refrigerated.

Forty specimens were obtained at consecutive, personally performed autopsies from the routine material of two hospitals. For reasons described in detail below, three specimens were omitted from the series. The remaining 37 specimens were taken from subjects which died of extrathoracic non-vascular



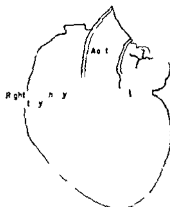
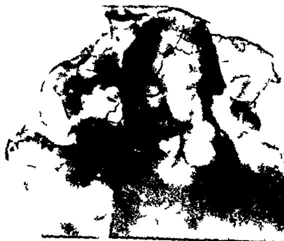


Fig 3 Anteroposter or view bronchial artery injectio 1 C ntrast f ll ng of minor atrial vessels 1 1 the l ft atr um Old posterior myocard ial infarct (Only a minute bronchial artery could be identified n the se erely art r osclerotic a rta A contrast depot developed early in the injection proc dure)





F g 4 Ante oposteri r iew bronch al artery inject on Contrast fill ng of a major at ial vessel (s nus node a tery) reaching a branch of right ventricular co onary artery w thout contra t med um being sible in the artery

diseases (18), vascular diseases of the brain (10), myocardial infarction (7), massive pulmonary embolism (1) and ruptured thoracic aortic aneurysm (1).

In addition to the patient which died from massive pulmonary embolism, three more patients had small pulmonary emboli. Another two patients had pericardial adhesions. None in the series suffered from cirrhosis of the liver. The age distribution and the degree of coronary stenosis as evaluated by the method described below are given in Table 1. The heart weight and myocardial changes are given in Table 2, where it is apparent that at least 18 subjects had an anatomically normal heart.

Newborn infants. The interval between death and autopsy ranged from 6 hours to 5 days during which period the bodies were refrigerated. Specimens taken from eight consecutive autopsies were examined. None of the infants had lived for more than two days and seven of them were born at full term. One was a premature weighing 1100 g and the main cause of death was considered to be the pulmonary lesions (hyaline membrane disease, hemorrhage, aspiration). Two of the full term infants died during delivery. The main diagnoses for the remaining five were intracranial hemorrhage (3), pulmonary lesions (1) and congenital aortic valvular stenosis (1).

Injection technique. At autopsy of the adults the chest organs were carefully taken out en bloc and separated from the abdominal organs subdiaphragmatically. The proximal and distal parts of the oesophagus were ligated and the descending aorta was opened dorsally. A sponge was placed in the aortic arch to prevent backflow into the ascending aorta. A main bronchial artery was then identified and injected with contrast medium through a polythene tube (most often with 2 mm outside diameter). Since the artery was tortuous it was not possible to put a ligature around the vessel and catheter. Although the largest possible tube was used, a minor back flow of contrast medium could not be eliminated. Since the bronchial arteries anastomose in the mediastinum, contrast material leaked back into the aorta from other bronchial or intercostal arteries. Minor vessels were ligated, major arteries were injected after ligature of the artery first injected. In three of forty subjects a major bronchial artery could not be identified and the injection was then performed into the widest right upper aortic intercostal artery after ligation of its peripheral part about 3 cm from the aorta.

The chest organs of the newborn infants were taken out in the same manner as in the adults. Then the aortic arch, the ductus arteriosus, the left carotid, the left subclavian and the thoracic aortic intercostal arteries were ligated. A catheter was put into the thoracic aorta at the diaphragmatic level. A ligature was put around the aorta and the catheter before injection.

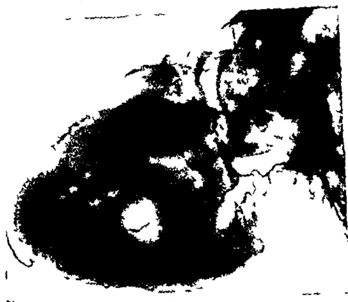




Fig 6 Lateral view bronchial artery injection Contrast filling of the left circumflex coronary artery via the sinus node artery

It was not possible to set a limit as to the amount of contrast medium needed for adequate contrast filling because of leakage of contrast medium and the presence of intrapulmonary anastomoses between the bronchial and pulmonary arteries In the adults it was found possible to terminate the injection when contrast medium had been visible in vessels on the pleural surfaces for about ten minutes If leakage was not excessive the amount of contrast medium injected varied between 10 and 40 ml In the newborn series the injection lasted for 45 minutes the time limit was set because of simultaneous investigation of the pulmonary vasculature on the same material



Fig 5 Anteroposterior view bronchial artery injection Contrast filling of the right coronary artery via the sinus node artery Tortuous vessels in the mediastinum anastomoses between the bronchial and pulmonary arteries and calcification in the left ventricular coronary arteries are also visible

The specimens were at room temperature during injection In two of forty adults the thoracic organs were cool when taken out from the body For conformity with the rest of the material the organs were suspended in a warm water bath before injection

All injections were carried out with the pressure retort described by LJUNGQVIST (1963) The injection pressure was kept at a maximum of 120 mm Hg

Injection material An aqueous suspension of microcrystalline barium sulphate (Micropaque) which has a particle size of 5 to 6 μ was used as contrast medium (GRANT 1965) For the adult series, a 25 % suspension was prepared and 3 % gelatine added The gelatine proportion was chosen after pilot experiments in order to facilitate solidification of the contrast medium at room temperature and thereby to reduce leakage at later operations The contrast medium was kept at about 40° C for injection For the newborn infants the contrast medium was a 7 5 % barium suspension without gelatine This medium was selected because of a parallel investigation of the pulmonary vasculature on the same autopsy material

Table 3

Contrast filled arteries in the heart after post mortem angiography via the bronchial arteries

Cardial arteries	Number of cases	
	Adults (37)	Newborn infants (8)
Minor atrial vessels	6	1
Major atrial vessels	3	
Ventricular arteries		
Right (R)	10	1
Left descending (LD)	1	
Left circumflex (LC)	9	2
R + LC	7	3
R + LD	1	
LC + LD		1
Ventricular arteries, total	28	7

compressed by the pericardial contents These three specimens were therefore omitted from the series and the material thus comprises specimens from 37 subjects

The technique resulted in filling of the bronchial arteries in both lungs in 33 specimens In two specimens only arteries in the right lung were filled with contrast material and in two other filling occurred in arteries in the left lung only Judging from the anteroposterior radiograms of the lungs anastomoses between the bronchial and pulmonary arteries were present in 26 subjects

The radiograms of the heart were scrutinized for the presence of contrast medium in the vessels These vessels were classified in the following increasing scale

I Small atrial vessels usually situated around the ostia of the veins (pulmonary inferior or superior vena cava) (6 specimens) Fig 3

II Major atrial vessels that reached a branch of a ventricular coronary artery without contrast medium being visible in the artery (3 specimens) Fig 4

III Ventricular coronary arteries (right, left descending and left circumflex) (28 specimens) Figs 5 to 7 In 20 of the latter specimens only one of the coronary arteries at ventricular level was filled but in 8 specimens both the right and the left arteries were filled with contrast medium (Table 3)

In most hearts it was possible to identify the afferent atrial vessel to the main coronary artery at ventricular level (Table 4) It was however difficult to distinguish between the minor left atrial arteries — the anterior intermediate

Radiographic procedures After completion of the injection, radiograms of the specimens were obtained at 72 kV and 12 mA, using Gevaert Osray films without intensifying screens and an exposure time that varied between 0 5 to 3 0 sec The focus film distance was 1 5 meters The projections were an antero-posterior view of chest organs with and without the pericardium, a lateral view of the heart and mediastinum with the lungs removed, and an antero posterior view of the isolated heart The right and left sides of the heart were then separated along the interventricular septum and radiograms were taken of the sides separately

Method of correlation with atheromatosis In order to find out whether a correlation existed between the presence of extracardial anastomoses and coronary atheromatosis, the degree of stenosis of the coronary arteries was determined according to the method described by LOBER (1953) After radiography of the adult hearts, about 5 cm of the first part of the three main coronary arterial branches were cut out In this respect the left main stem was regarded as part of the left descending artery After fixation for 2 to 3 days in 10 % neutral formalin, and decalcification if necessary, each branch was sectioned transversely at approximately 3 mm intervals The sections of the artery which showed the greatest degree of stenosis were taken for microscopic examination Five blocks were taken from each branch of the coronary arteries The sections were stained with a combination of van Gieson s connective tissue and Weigert s elastic tissue stains

The lumen area was determined with an ocular micrometer using two approximately perpendicular measurements The degree of stenosis was expressed as a percentage of the cross section area of the lumen to the cross section area of the entire artery calculated as the area within the external elastic lamina The greatest degree of stenosis was taken as the value for the coronary branch in question (see Table 1)

Results

Adults Vessels within the heart at atrial or ventricular level, were filled with contrast material in 37 of the 40 specimens examined In one specimen the oesophagus was autolyzed and filled with contrast medium when the injection was terminated In another the injection resulted in a massive contrast depot in the region of the bronchial arteries, most likely due to a rupture of the bronchial arteries either by the catheter or by damage of tissue when the organs were taken out of the body A third subject had recent myocardial infarction with rupture and haemopericardium The pericardial blood was not removed before the injection and the atrial vessels had probably been



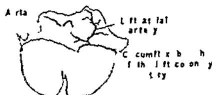


Fig 7 Anteroposterior view of the opened left side of the heart of an infant born about term bronchial artery injection Contrast filling of the left circumflex coronary artery via one of the left atrial arteries

were demonstrated in only 2 out of these 6 specimens but in 24 of 31 specimens (77 %) in the rest of the material this implies a generally poor contrast filling in the six specimens Artefacts autolysis of the oesophagus or large barium depots in the mediastinum could be demonstrated in each of these 6 specimens

Newborn infants Using the same classification of vessels within the heart as in the adults anastomoses do in to coronary arteries at ventricular level were demonstrated in seven infants (Fig 7 Tables 3 and 4) The eighth a full term infant that died during delivery was unsuccessfully injected contrast medium was visible only in arteries in the left lower lobe and in the heart only minor atrial vessels in the region of the pulmonary veins were filled

Discussion

Post mortem angiography always involves elements of error Filling of a vessel might be hindered or made impossible by post mortem clots The bronchial arteries supply not only the lungs but also mediastinal organs such as the oesophagus Defects in the oesophageal wall ulceration or autolysis must lead to a considerable loss of the amount of contrast medium injected In some subjects the bronchial arteries anastomose with the pulmonary arteries in the lungs and these anastomoses give another possibility for a loss of contrast medium It is therefore impossible to state the amount of contrast medium needed to obtain adequate filling of the bronchial arteries Within the bronchial arterial system as a whole there will inevitably be small areas not filled with contrast medium

Table 4

Intracardiac pathways to ventricular arteries after post mortem angiography via the bronchial arteries

Ventricular artery	Afferent vessel	Number of cases	
		Adults	Newborn infants
Right via	Sinus node artery	14	4
	Left atrial arteries	1	
	Not definitely identified	3	
Left descending via	Vasa vasorum aortae	1	
	Not definitely identified	1	1
Left circumflex via	Left atrial arteries	12	5
	Sinus node artery	3	
	Sinus node and the left atrial arteries	1	
	Not definitely identified		1

or posterior — and the arteries were therefore jointly designated as the left atrial arteries

There was no consistent correlation between the pattern of filling the one, the other or both coronary arteries and the degree of coronary stenosis as measured in the manner described

In 28 of the 37 specimens, coronary arteries at the ventricular level were filled (Table 3) In another three specimens, contrast medium was identified in major atrial vessels, reaching but not filling the coronary arteries at the ventricular level Since any form of post mortem angiography will scarcely give a total outline of the vascular bed, it seems justified to regard these three specimens as representing potential anastomoses to the ventricular area and to add them to the 28 previously mentioned

Accordingly, the adult material included 6 specimens apparently unsuccessfully injected, e g only small atrial vessels situated in the regions of the vein inlets were filled Attempts were made to correlate these specimens and the whole material to age and degree of coronary stenosis in individual branches (Table 1), heart weight and myocardial changes (Table 2), pericardial adhesions and the time lapse between death of the patient and autopsy No correlation could be obtained A female predominance however, was noted, but the material was small and it did not seem justified to draw any conclusions on this point Anastomoses between the bronchial and pulmonary arteries

SUMMARY

Anastomoses between the bronchial arteries and the coronary arteries were studied in hearts from 40 adults and 8 newborn infants after the post mortem injection of contrast medium and radiography With the exception of the few specimens with artefacts anastomoses at least precapillary could be demonstrated between the bronchial arteries and the coronary arteries at the ventricular level in all the subjects examined regardless of age sex myocardial changes or the degree of coronary atheromatosis

ZUSAMMENFASSUNG

Anastomosen zwischen den Bronchialarterien und den Koronararterien wurden radiographisch in den Herzen von 40 Erwachsenen und 8 Sauglingen nach post mortem Injektion von Kontrastmittel studiert Mit Ausnahme von den wenigen Praparaten mit Artefakten konnten Anastomosen zu mindest als prekapillare zwischen den Bronchialarterien und den Koronararterien der Ventrikel in allen untersuchten Praparaten ohne Rucksicht auf Alter Geschlecht Herzmuskelveranderungen oder den Grad der Koronaratheromatose demonstriert werden

RÉSUMÉ

L auteur a étudié sur 40 adultes et 8 nouveau nes par injection post mortem de moyen de contraste et radiographie les anastomoses entre les arteres bronchiques et les artères coronaires du coeur A l exception de quelques pièces comportant des artéfacts on a pu mettre en évidence des anastomoses au moins précapillaires entre les arteres bronchiques et les artères coronaires au niveau des ventricles chez tous les sujets examinés quels que fussent leur age leur sexe les lésions myocardiques ou le degré d athérome coronarien

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Because of the inherent difficulties in post mortem angiography, those specimens with obvious artefacts (6 of 37 adult specimens) can be discarded. The observation on the adult material gives strong support to the idea that extracardial anastomoses to the heart via the bronchial arteries always exist. This idea is further supported by the findings in the eight newborn infants. With the exception of one technically unsuccessful injection, contrast medium was noted in the ventricular coronary arteries in all the infants.

From the present material it therefore seems justified to state that anastomoses from the bronchial arteries to the coronary arteries exist at all ages in human beings. Thus no correlation has been found between the occurrence of these anastomoses and age, heart weight or coronary atheromatosis as proposed by HUDSON, MORITZ & WAERN (1932), SCHOENMACKERS (1954), and SCHOENMACKERS & VIETEN (1954).

The functional and clinical significance of the extracardial anastomoses is difficult to determine from the present material. The contrast medium for the adult material was a 25 % barium suspension with 3 % gelatine added. The medium had a fairly high viscosity and in spite of the small particular size (5 to 6 μ) of the barium salt it did not give appreciable capillary filling. This implies that the anastomoses are at least precapillary. Measurements on the radiograms and on microangiograms (MOBERG, to be published) have indicated that the anastomoses range from 50 to 200 μ in diameter, but in one case anastomoses of about 1 mm in diameter have been identified. This estimation of calibre agrees with that of FULTON (1963) who found an extracardiac communication with a maximum diameter of 800 μ in a 14 year old boy. Functional anastomoses, as opposed to anatomical communications, have been defined for mammalian hearts as those above 40 μ in diameter (BLUMGART 1959, GREGG & FISCHER 1963). Even so the measurements in this report are from post mortem material without vascular tonus, or the like, and conclusions as to the functional significance of the extracardial anastomoses cannot be made at this stage. This problem will be discussed in greater detail in a coming report.

Addendum in the proofs

After completion of this paper three articles by PETTLENZ (1965) have appeared in which he refers to a preliminary report (1963) dealing with extracardial anastomoses by means of post mortem bronchial angiography. This author's conclusions will be discussed in a forthcoming paper.

A complete list of our case records with all pertinent data can be obtained from the author.

FROM THE CENTRAL INSTITUTE OF RADIOLOGY (DIRECTOR JOSEPH WELLAUER) ZURICH SWITZERLAND AND THE DEPARTMENT OF THORACIC RADIOLOGY (DIRECTOR BJORN NORDENSTROM), KAROLINSKA SJUKHUSET STOCKHOLM SWEDEN

IMMINENT CARDIAC TAMPONADE FOLLOWING CONTRAST EXAMINATION OF THE HEART

by

BJORN NORDENSTROM

It is remarkable that reports of complications and risks in the field of heart catheterization should be so rare in view of the large number of such procedures performed nowadays A few reports (BAGGER et coll 1957, DERRA 1959) exist however although discussions with colleagues with a wide experience of heart catheterization suggest that serious sequelae in connection with this measure are now relatively rare Despite various precautions occasional untoward occurrences cannot however, be avoided and awareness of this fact and an extended knowledge of the ways in which complications arise the signs they provoke and the possibilities there are of coping with them are thus of great importance Perforation of the heart wall with collection of fluid in the pericardium in connection with selective catheterization and cardioangiography will be discussed in this paper

Considerable circulatory changes may occur in connection with the sudden accumulation of pericardial fluid Detailed information on this subject is given in textbooks of physiology (WIGGERS 1935 EVANS 1939 and others) Certain

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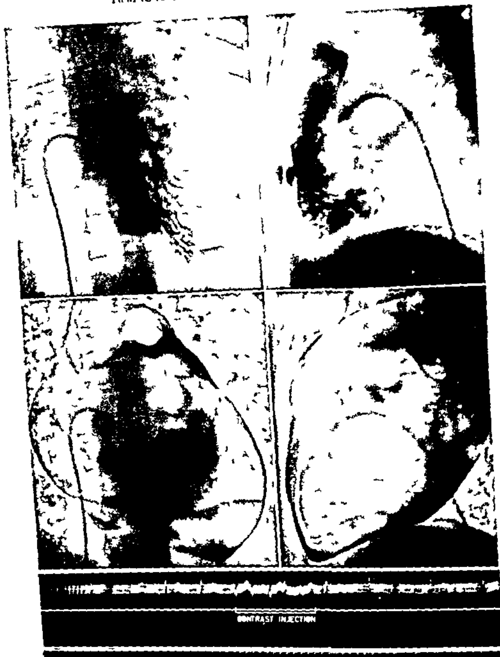


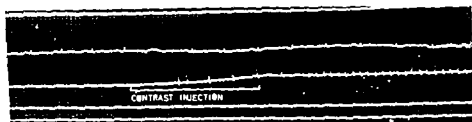
Fig 1 *Upper roentgenograms* Injection of contrast medium into the right ventricle with commencing perforation of the anterior ventricular wall *Lower roentgenograms* A large part of the medium lies in the pericardial cavity at the end of the injection The *EEG* shows that there were only a few extrasystoles during the injection

points should, however, be emphasized The pericardial sac is but little distensible, which means that fluid in the cavity may cause cardiac tamponade No definitely demonstrable enlargement of the heart and pericardium is therefore to be expected as a result of any sudden fluid accumulation in the pericardial cavity In cases of exudative pericarditis, on the other hand, the pericardium may be considerably distended Whether this is chiefly due to a pressure increase of relatively long duration, or to a combination of the latter with inflammatory changes in the pericardial tissue has not yet been elucidated A collection of pericardial fluid, however, frequently gives rise to certain electrocardiographic disturbances at low voltage Hemodynamically, the condition is *dominated by the hindrance to the filling of the heart With rising* pressure in the pericardium, appreciable disturbances in the circulation occur only when the pericardial pressure begins to exceed the intrathoracic venous *pressure This limit is reached only after continuous increase of the venous* pressure during earlier phases of the pericardial increase in pressure The critical pericardial pressure at which the filling of the ventricles is appreciably impeded is considered to amount to 10 to 15 cm of water There is then a rapid fall in the arterial pressure, which is reflected more by the systolic than by the diastolic pressure A so called paradoxical pulse often ensues during the increase of the pericardial pressure This is characterized by a palpably demonstrable increased fullness of pulse during expiration and decreased fullness during inspiration and is considered to be due to the distribution of the respiratory pressure variations in the thorax Distension of the pericardium by fluid protects the ventricles from the respiratory pressure variations The extra cardiac intrathoracic venous pressure, on the other hand, sinks considerably during inspiration and increases during expiration This gives rise to marked variations in the effective *filling pressure of* the ventricles, synchronously with the respiration The ventricles will accordingly vary in output Thus, as the filling of the ventricles will increase *during expiration, the most strongly palpable peripheral pulse* will also occur during expiration

The flaws in the examination technique will be analyzed in the present article in certain cases in which imminent cardiac tamponade ensued through hemorrhage or injection of contrast medium into the pericardium These complications comprise two perforations of the wall of the right ventricle in connection with injection of medium through a catheter, one case of hemopericardium after transseptal puncture of the left atrium, and one case of perforation of the left ventricle in connection with selective injection of contrast medium through a catheter Finally, clinically demonstrable changes of different degrees, as in hemopericardium, have been observable *in 10 to 15*

a

b



c

Fig. 2. Injection of contrast medium into the main trunk of the pulmonary artery caused the catheter to recoil to the right ventricle, the anterior wall of which was perforated by the jet of medium through the terminal hole in the catheter a) and b) Large amount of medium in the pericardium. The ECG shows only one extra systole at the beginning of the injection

ginning of the injection and no electrographically recordable changes in lead I were otherwise observed (Fig. 2c)

No noteworthy symptoms or signs were observed during or immediately after the examination. Routine fluoroscopic control of the heart carried out after injection of contrast medium disclosed that the greater part of it had been deposited in the pericardial cavity. The systolic blood pressure was 130 but

cases in connection with transthoracic puncture of the left ventricle for pressure measurements and the injection of contrast medium

These complications with the injection of medium or only bleeding into the pericardium have been observed in approximately 1 500 angiocardiographic examinations, the latter comprising the injection of medium into the right atrium, right ventricle, left atrium or left ventricle Two injections of contrast medium in some instances have been given at one and the same examination

Perforation of the right ventricular wall The first case was one of a 38 year old woman who was examined without general anesthesia with the preliminary diagnosis of mitral stenosis A so called yellow Ödman catheter with a terminal hole of 0 9 mm diameter and 6 lateral holes each with a diameter of 1 1 mm was placed with its tip in the upper part of the right ventricle as shown in Fig 1 A control injection of 15 ml Urografin 76 % was given, followed by a main injection of 90 ml Urografin 76 % (1 5 ml per kg bodyweight) in 1 5 seconds At the very beginning of the injection, part of the medium passed through the terminal hole of the catheter, which was immediately adjacent to the middle part of the ventricular wall through the myocardium to the pericardium (the upper views in Fig 1) Only two extra systoles occurred during the first part of the injection No other electrocardiographic changes were evident in the ECG tracing (lead II) The patient stated that she felt no particular sensations after the injection Continuous supervision with control of blood pressure and pulse frequency was carried out, and after about an hour the systolic blood pressure sank below 100 mm Hg Transventricular commissurotomy for the mitral stenosis was then performed The operation revealed a hematoma in the anterior wall of the heart, and when a clot was removed a thin jet of blood spurted out The perforation hole was closed with two sutures Nothing noteworthy occurred in the postoperative period

The second case was one of a 15 year old woman under examination for mitral stenosis The tip of a yellow Ödman catheter with a terminal hole and multiple lateral holes was placed in the main trunk of the pulmonary artery A control injection of 15 ml Urografin 76 % was followed by the injection of 60 ml Urografin 76 % (1 ml per kg bodyweight) in just under 3 seconds At the very beginning of the injection the catheter recoiled to the conus arteria pulmonalis, so that the terminal hole was positioned at right angles to the anterior ventricular wall The jet of medium obviously penetrated via the thin terminal hole of the catheter (Fig 2, a and b), so that a large part came to be deposited in the pericardial cavity Only one extra systole ensued at the be

of contrast medium which indicated that the tip lay in the middle part of the left atrium About 10 to 15 minutes after the puncture of the atrial septum the blood pressure sank rapidly to below 70 mm Hg A pericardial tamponade was obviously developing a catheter was therefore introduced into the pericardium and about 150 ml blood withdrawn The blood pressure then rose to 120 mm Hg The catheter was left in the pericardium for a further two hours but no more blood could be sucked from the pericardium and there was no further fall in blood pressure

Perforation of the left ventricular wall A 33 year old man with clinical signs of aortic stenosis was examined by retrograde catheterization of the left ventricle with a yellow Ödman catheter with a terminal hole and multiple lateral holes Pressure measurements with the catheter in the left ventricle indicated an intraventricular pressure gradient of 80 mm Hg The tip of the catheter was placed in the posterior part of the left ventricle and 1 ml per kg body weight Urografin 76 % was injected at a pressure of 6 kg per cm^2 applied to the plunger of a Gidlund injection syringe Fluoroscopic control of the heart after the injection disclosed that a large part of the contrast medium had passed via the tip of the catheter through the posterior wall of the left ventricle into the pericardium (Fig 3) Subvalvular membranous aortic stenosis was present in this case Some of the medium had also been deposited in the left ventricular wall and was being drained by the coronary veins Although a large part of the medium lay in the pericardial cavity there was no effect on the blood pressure in the aorta immediately after the injection The systolic blood pressure gradually sank to about 80 in the course of about 3 hours during which period frequent controls of blood pressure and pulse frequency were carried out At the same time moderate bradycardia appeared

The pericardial cavity was then catheterized and about 120 ml of blood and contrast medium were withdrawn The blood pressure had gradually risen to about 120 mm Hg and as this level was maintained it was possible after a further few hours to withdraw the catheter There was no further serious effect upon the blood pressure

Hemopericardium in connection with transthoracic puncture of the left ventricle Evidence of hemopericardium was present in about 15 out of the approximately 150 cases in which transthoracic puncture of the left ventricle was performed and in several of these small amounts of contrast medium passed along the needle to the pericardium during the injection All of these 15 cases had a more or less marked fall in blood pressure as a rule not below

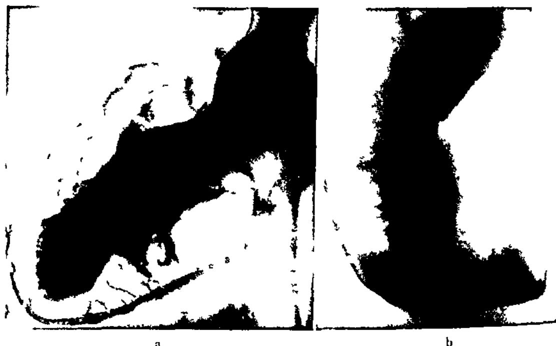


Fig 3 Subvalvular membranous aortic stenosis left posterior oblique 45° projection (a) and right posterior oblique projection (b). Injection of contrast medium into the left ventricle via a catheter with the tip resting against the posterior wall of the ventricle. The medium passes from the terminal hole of the catheter through the myocardium into the pericardial cavity, part of the medium is rapidly resorbed from the myocardium and fills the coronary veins

in the course of the next 30 minutes it sank successively to 80 mm Hg. At the same time the patient broke into a cold sweat and had difficulty in talking. No signs of any marked stasis in the veins of the neck were present. Acute cardiac tamponade was obviously developing and evidently threatening the patient's life. The pericardium was then catheterized in a way that will be described later, and about 120 ml of blood mixed with contrast medium was withdrawn via the catheter. The blood pressure returned rapidly to normal and other evidence of circulatory collapse disappeared.

Hemopericardium after transseptal puncture of the left atrium. Transseptal puncture of the left atrium was performed in a woman with mitral stenosis. A modified Ross puncture needle (1, 2) was introduced from the right femoral vein by the percutaneous technique. During the examination the point of the needle accidentally perforated the posterior left atrial wall after its passage through the atrial septum. A heart catheter having been introduced into the left atrium, its position was controlled in the usual way with a test injection

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100 mm Hg, although in some cases the pressure sank to between 80 and 90 Stasis in the veins of the neck was sometimes observed A change in heart rate was unusual but bradycardia occasionally occurred All the cases with more serious indications of cardiac tamponade had bradycardia low blood pressure, pale complexion, cold perspiration, no signs of venous stasis, and an electrocardiographically recorded low voltage

Thoracotomy was performed to control the hemorrhage to the pericardium that was considered to exist in two cases of valvular aortic stenosis and in one case of asymmetric hypertrophy of the left ventricle A thin jet of blood was at operation seen to spurt through the puncture channel at every systolic beat in all three cases A small suture over the perforation was sufficient to control the bleeding

Discussion

These cases of imminent cardiac tamponade should be more than sufficient to draw attention to this complication in connection with contrast examinations of the heart Catheterization of the heart in itself implies a potential risk of perforating the wall As regards the perforation of the right and left ventricles, it seems likely that the catheters were wrongly positioned during the final contrast injection In these three cases, as always, the position of the catheters was controlled with test injections of 10 to 15 ml contrast medium by hand, during which no signs of incorrect positioning of the catheters could be observed But even when the catheter seems to be correctly placed, its position may be somewhat changed by heart contractions or from other causes during the interval between the test and the final injection of the larger dose of contrast medium In the case with contrast injection through a catheter in the left ventricle, technical reasons made it necessary to move the patient on the examination table a short distance to the film changer which of course increased the risk of a change in the original positioning of the catheter

The tip of the catheter in these examinations has been furnished with a terminal hole and multiple lateral holes The terminal hole has been necessary because the percutaneous technique has been applied for the introduction of the catheter In the cases now presented, the perforation of the heart wall occurred axially in relation to the catheter and seems to have been caused by the jet of contrast medium The recoil of the catheter from the pulmonary artery to the right ventricle was undoubtedly caused by the jet of medium through the terminal hole in the catheter It thus seems as if the advantages accruing with the present percutaneous catheterization technique are largely outweighed by the necessity for a terminal hole in the catheter

As regards the injection of contrast medium into the right and left ventricle it seems possible that during the ventricular systole the wall of the ventricle may have contracted around the catheter during the injection The penetrative effect of the jet of fluid would considerably increase in that way

The curved cannula had to be directed backwards in the transseptal puncture of the left atrium As in this case the puncture of the atrial wall was undertaken under fluoroscopic control in the anteroposterior projection, it was not possible to ensure that after its passage through the atrial septum the needle did not also pass through the posterior atrial wall Through the resistance of the atrial septum to the cannula it is possible that the former may have been pushed backwards towards the posterior atrial wall This risk factor might thus be better controlled if the puncture is undertaken under fluoroscopic control of the patient not only in the a p projection but also in the lateral one

These cases have demonstrated that careful fluoroscopic control of the position of the catheter and test injections of medium are not always a guarantee that no complications arise later in connection with the rapid injection of the larger amount of contrast medium

The injection of medium into the left ventricle after transthoracic puncture of the ventricle has generally been performed in cases with severe valvular or subvalvular aortic stenosis in which it has been impossible to catheterize the left ventricle in a retrograde direction from the aorta Considerable hypertrophy of the musculature of the left ventricle due to the aortic stenosis has generally also existed Furthermore in cases with marked hypertrophy of the ventricular musculature the latter is relatively thin near the apex of the heart In those cases in which a dangerous hemorrhage into the pericardial cavity has arisen after puncture of the ventricle the needle has passed through or in the vicinity of the apex of the heart It is therefore conceivable that blood is then pressed through the puncture hole in the apex into the pericardium more easily than if the hole in the ventricle had been located in a part of the ventricular wall with a more strongly developed musculature On this account and because of the risks of encountering the anterior or posterior descending coronary artery at the apex the punctures are now performed 3 to 4 cm laterally upwards measured from the apex The needle thus passes through a less vascularized region of the myocardium with respect to the presence of large coronary arteries Furthermore the puncture channel is given an oblique direction through a thicker part of the ventricular wall

Both the test and the final injections into the ventricle are now performed with the help of image intensifier and television equipment This has proved to be of very great value for the correct placing of heart catheters and puncture needles and control injections of contrast medium

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In the three cases of imminent cardiac tamponade described in this paper, the fluid in the pericardial cavity was removed through catheterization of the pericardial cavity This resulted in a dramatic improvement of the patient's condition Rapid and correct diagnosis and right therapy are of paramount importance in complications There is no doubt but that a rapid removal of the fluid in the pericardial cavity may save the patient's life As the technique used for catheterization of the pericardial cavity may also have other fields of application, an account of this will be given in a later report Catheterization of the pericardial space appears to the writer to be the best method for rapid and sure removal of pericardial fluid However, the withdrawal of blood and contrast medium may of course also be performed in connection with a conventional puncture of the pericardium If signs of persistent hemorrhage appear it will of course be necessary to close the perforation after surgical exposure of the heart

SUMMARY

The investigation comprised an analysis of the causes of certain iatrogenic perforations of the cardiac wall in connection with contrast examinations of the heart The signs that may arise the possibilities of avoiding perforation of the wall and the importance of early removal of blood and contrast medium from the pericardial cavity are discussed

ZUSAMMENFASSUNG

Die Ursache der Perforationen der Herzwand bei ärztlichen Eingriffen besonders bei Kontrastuntersuchungen wurde untersucht Die Anzeichen einer Perforation Wege um eine Perforation zu vermeiden und die Wichtigkeit Blut und Kontrastmittel prompt vom Herzbeutel zu entfernen werden besonders erörtert

RÉSUMÉ

Ce travail comporte une étude des causes de certaines perforations instrumentales de la paroi du coeur au cours d'examens cardiaques avec un moyen de contraste Les auteurs étudient les signes qui peuvent apparaître les possibilités d'éviter la perforation de la paroi et l'importance de l'évacuation précoce du sang et du moyen de contraste hors de la cavité péricardique

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Bilateral sactosalpinx with papillomatous changes

impossible to make the diagnosis preoperatively VLADAR (1955) and BLOCK (1947) and others described in all 16 cases in none of which the diagnosis was made before laparotomy ENNKER (1955) maintained that among 100 cases of carcinoma of the fallopian tubes during latter years only 26 had been diagnosed prior to operation but according to FORBES & FINLAYSON (1931) only two cases have been reported in which a clinical diagnosis could be made As carcinoma of the fallopian tubes is often connected with other changes, such as myoma ovarian cysts hydrosalpinx etc the diagnosis is not easy Vaginal discharge, pain in the true pelvis and enlargement of the adnexa despite a normal vagina cervix, and uterus following curettage should suggest the presence of a growth Intermittent hydrosalpinx is believed to be a common sign the pain ceases and a sudden heavy discoloured serous discharge appears often with the disappearance of a unilateral swelling of the true pelvis This of course also occurs in hydrosalpinx but if the discharge is serosanguineous or brownish the possibility of a tumour of the fallopian tubes should not be overlooked A positive cytologic test from the vaginal discharge may constitute evidence of a growth of the fallopian tubes even if there are no changes in the cervix or the endometrium after curettage The diagnosis may be made after biopsy in connection with colposcopy (MILLER 1948 PAPSON 1939 KISS JOZA & LUSZTIG 1961) due to the risk of spread however this method is not recommended

The processes are generally localized to the distal third of the tube and are

FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR CURT JOHANSSON)
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PRIMARY CARCINOMA OF THE FALLOPIAN TUBES

Report of a case

by

H. REGNER

Primary carcinoma of the fallopian tubes is uncommon, only about 500 cases in all having been reported. According to MILLER (1918) the diagnosis constituted 0.1 % of the 2 500 cases of carcinoma of the uterus, ovaries and tubes. The frequency of carcinoma in cases operated on for diseases of the tubes varied from 0.34 to 1.53 per cent (HERBUT 1953). KISS, JOZA & LUSZTIG (1961) reported that during the previous three years nearly 200 cases had been described, while during the previous 70 years only 500 cases had been mentioned in the literature.

The ages vary between 18 and 80 years (HERBUT 1953), and according to SHERMAN (1963) from 30 and 70 years with a mean of 45 to 55 years. The most frequent type of tumour is adenocarcinoma but sarcoma, endothelioma, lymphosarcoma and a mixed tumour are sometimes encountered. There are three types of adenocarcinoma, viz. papilloadenomatous and medullar. The diagnosis of primary carcinoma of the fallopian tubes is seldom made prior to operation (MORTON & SCHNEIDER 1947) and some authors believe it

Submitted for publication 22 March 1965.

Discussion

Carcinoma of the fallopian tubes is a comparatively rare condition It has sometimes been encountered during recent years but the diagnosis has seldom been made prior to operation It is remarkable that a roentgenologic examination is rarely performed for the changes caused by the growth seem to be readily demonstrable

SUMMARY

Primary carcinoma of the fallopian tubes including the more common clinical signs are discussed A case in which hysterosalpingography revealed a large bilateral sactosalpinx with papillomatous changes in both tubes caused by adenocarcinoma is described

ZUSAMMENFASSUNG

Das primare Karzinom der Eileiter und dessen klinische Symptomatologie werden besprochen Ein Fall wird mitgeteilt in dem die Salpingographie beiderseits zwei grosse sack förmige Tuben mit papillomatosen Veranderungen zeigte Es handelte sich um ein Adeno-Karzinom

RÉSUMÉ

L auteur décrit le cancer primitif des trompes de Fallope avec ses signes les plus fréquents Il présente un cas ou l hystérosalpingographie a montre une grosse tumeur salpingienne bilatérale avec lésions papillomateuses due à un adénocarcinome

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unilateral in 95 per cent of cases (CORSCADEN 1962). The tube towards the fimbria is always closed. The tube is swollen and sausage shaped with a smooth and shiny surface, the colour being dark red or blue. The process slowly permeates the muscularis. The surface of the peritoneum is of importance at operation in the primary differential diagnosis of primary or secondary carcinoma. The reason is that metastases are usually found in the tubes, in carcinoma of the endometrium, with continuous growth via the lymph nodes or as part of a generalized peritoneal spread. The fallopian tubes also collect metastases originating from gastrointestinal or mammary carcinoma. The literature on the subject seldom suggests hysterosalpingography although ANTONOVITSCH (1950) described two cases that had been diagnosed by the method. LEIENNITIEI, ROUQUET & PICARD (1956) described roentgenograms of a specimen obtained at operation. Kiss et coll. stated that the advantages of hysterosalpingography were rather dubious and that the method was not entirely safe. NORMAN (1957), in describing hysterosalpingography in carcinoma of the uterus, reported no criteria involving any risk of implantation metastases.

Case report

Woman aged 47, one pregnancy, para I, was treated in 1950 for acute salpingitis. Penicillin produced freedom from signs after 3 to 4 weeks. Treated in 1956 for menometrorrhagia: histologic examination revealed a secreting mucous membrane without demonstrable pathologic signs. Renewed irregular haemorrhages resulted in curettage, the histologic examination then disclosing a secreting mucous membrane in desquamation and benign polypi.

Six years later the patient stated that she had had a discoloured discharge for two years and complained of a feeling of swelling in the lower part of the abdomen. Palpation and inspection revealed no abnormal signs. The patient complained again of discharge and haemorrhages of varying degrees and pain on the right side. A swelling was found high up in the abdomen and hysterosalpingography revealed a bilateral sactosalpinx, the largest diameters being 3 and 5 cm on the left and right sides respectively. A multitude of dimpled polypoid growths were present in the sactosalpinx on both sides. The cavity of the uterus was enlarged with a maximum diameter of 5 cm; a slightly irregular, rounded defect was present in the filling of the isthmus with a maximum diameter of about 2 cm and suggestive of a submucous myoma.

Operation. Hysterectomy with bilateral salpingoophorectomy. A hen's egg sized sactosalpinx and small adherent ovaries were present on both sides. No abnormal signs evident upon abdominal palpation. Postoperative course normal.

Histologic examination. Papillary adenocarcinoma of both tubes with infiltration of the walls of the tubes, especially on the right side. Bilateral sactosalpinx + submucous myoma in the isthmus uteri + proliferation of the corpus mucosum + slight irritation of the endometrium at the ends of the tubes. No metastases in the ovaries. No tumour in the uterus.

The patient received cobolt treatment. At the follow up examinations up to one year after operation there was no evidence of recurrence nor of metastases.

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ASCENDING FRONTAL BRANCH OF MIDDLE CEREBRAL ARTERY

by

B ALBERT RING and MARGARET WADDINGTON

In a previous study (RING 1962) the radiographic anatomy of the middle cerebral artery was described and a method given of applying zones to the termination of the four major branches to facilitate their recognition This has been helpful in recognizing many cases of small vessel occlusion (RING 1963) but was incomplete in that the subdivisions of the ascending frontal artery which is as large as the other branches combined were not studied in detail The present work was undertaken to complete the first and is an anatomical and radiographic study of the ascending frontal branch of the middle cerebral artery

The nomenclature of the four major branches is quite standard, these being the ascending frontal posterior parietal angular and posterior temporal There is no standard division of the branches of the ascending frontal branch, however PEELE the neuroanatomist (1961) divides this complex into four subdivisions the orbitofrontal prerolandic, rolandic and anterior parietal LIMA (1950) described three subdivisions the orbitofrontal the inferior frontal

From the Department of Radiology (Director Prof A Bradley Soule) and the Division of Neurology (Director Prof George A Shumacher) University of Vermont College of Medicine and Affiliated Hospitals Burlington Vermont Submitted for publication 23 November 1965

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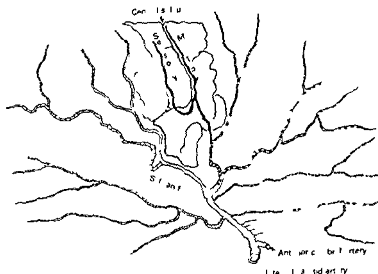


Fig 2 Schematic drawing representing vessels of the dissection specimen shown in fig 1 The central sulcus artery arises from the candelabra group

ramus which reaches the superior surface of the brain The next sulcus anterior to the marginal ramus is the central sulcus The position of the motor strip was further verified by the simple method emphasized by YARKOLEV (SINGER & YARKOLEV 1954) and illustrated in the text Sagittal sections were taken through the area The motor strip having five layers of neurons as opposed to three on the adjacent gyri has a thicker layer of cortical gray matter that is obvious on gross inspection

The frightening complexity of the middle cerebral artery as seen angiographically is due to the three dimensional course taken by the branches as they are enfolded under the operculum or pass at various depths in the sulci When the vessels are straightened by dissection they are little more complex than arteries elsewhere

One hundred normal lateral carotid angiograms in the arterial phase were traced on cellophane paper using different colors to identify the vessels By chance exactly 50 right and 50 left were traced 40 of these representing bilateral studies in 20 patients

Origin of the ascending frontal artery complex

The origin of the ascending frontal arteries off the main stem of the middle cerebral artery is quite variable and is often difficult to determine on angiograms There may be from one to four main trunks running separately in the

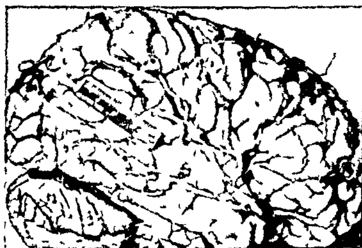


Fig. 1. Brain specimen with arteries placed over the sulci from which they were dissected.

and the prerolandic. KRAYENBUHL and YASARGIL (1965), in their most recent text, described four main branches of the ascending frontal, the orbitofrontal, precentral, central and anterior parietal. This nomenclature was not strictly followed in illustrations, however. JAIN (1964), in a recent paper on the anatomy of the middle cerebral artery, described only the branches proximal to the Sylvian fissure and the form of division of the main trunk of the middle cerebral artery. From the current study, it became apparent that there are three major subdivisions of the ascending branch that are constant and differ sufficiently in their course and origin to be readily identified on the lateral carotid angiogram. These three subdivisions we have termed, passing from anterior to posterior, the orbitofrontal, the candelabra group and the artery (or arteries) to the central sulcus.

Materials and Methods. Fifty middle cerebral arteries were dissected from twenty-five adult brain specimens without gross abnormalities from the routine post mortem services of the Mary Fletcher and DeGoesbriand Memorial hospitals. After pia-arachnoid and veins were removed, each branch was dissected and traced to its terminal arborization, and the vessel laid on the surface of the brain over the sulcus or gyrus where it normally coursed. Photographs of the specimen were taken in some cases, and each middle cerebral artery was drawn in detail, using different colors to identify the major subdivisions. On each of these drawings, the precentral and postcentral gyrus was depicted as accurately as possible, and the central sulcus identified. In order to locate the motor strip accurately, the criterion of SIDMAN & SIDMAN (1965) was used. The cingulate gyrus on the medial surface of the brain was traced to the marginal

Configuration	Brains	%	Angiograms	%
I	16	32	46	46
II	7	14	24	24
III	27	54	26	26
Unrecognized	0	0	4	4
Total	50	100	100	100

Fig 4 Schematic representation of the various configurations of the candelabra group with percentages of occurrence of the different forms II is a modification of I with one or two additional branches shown in dotted lines

while in the remainder this gyrus was supplied by branches of the pericallosal group With practice these vessels can be readily separated from the more posterior portion of the ascending frontal since their distal branches are directed anteriorly and upward while the vessel in the more posterior group pass almost directly upward to their terminal distribution

Candelabra group The next and largest complex of vessels are those that are enfolded in the insula and after emerging from under the operculum pass directly upward over the lateral aspect of the frontal lobe The term candelabra group is used in this paper for want of a better since it is descriptive and emphasizes the multiple nature of the arteries involved The most common form of the candelabra group is that of three vessels arising from one trunk and passing upward over the lateral aspect of the frontal lobe and subsequently bifurcating to give a total of six vessels on the superior portion of the frontal lobe Variations in this basic structure are common and in an appreciable number the basic structure is that of two vessels that bifurcate and rebifurcate as they pass upward In either case the design is very similar to a candelabrum

Artery (or arteries) of the central sulcus This vessel is remarkably constant as noted by Foix & Levy in 1927 but despite its importance in supplying the motor strip and as a potential landmark to the neurosurgeon it has

Configurations	Brains	%	Angiograms	%
	2	4	21	21
	10	20	22	22
	15	30	12	12
	23	46	17	17
Bizarre or untraceable Configurations	0	0	28	28
Total	50	100	100	100

Fig. 3. Schematic representation of the various configurations of the orbitofrontal artery and percentages of occurrence of the different forms.

Sylvian fissure, to supply this group but in the majority of cases (82 % of brains examined) the complex was fed from either one or two main trunks. In the case of multiple origins, the vessels tend to arise from the most superior artery in the Sylvian fissure which is either a main trunk supplying the posterior parietal and angular arteries, or the posterior parietal artery itself. None of the ascending frontal arteries were found to originate from the temporal vessels, and only on four angiograms did an ascending frontal vessel appear to arise from the angular artery.

Orbitofrontal artery. The term orbitofrontal artery is used universally by those who subdivide the ascending frontal complex and is the most anterior portion of the ascending frontal that supplies the inferior aspect of the frontal lobe. There was great disparity between brain specimens and angiograms in the study of this vessel, due in part to the confusing superimposition in the films of the pericallosal vessel. Primarily from brain dissections, this vessel was found to originate as either one trunk or as two or three separate vessels: one branch supplying the orbital surface of the brain, one the inferior frontal gyrus and one the middle frontal gyrus. In 17 (34 %) of brain specimens, the branches to the middle frontal gyrus extended to the superior frontal gyrus

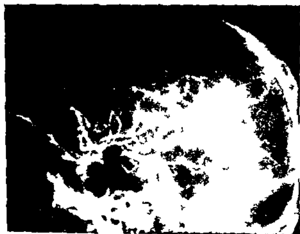


Fig 6 A normal carotid angiogram

superiorly In 42 % of brain dissections and 47 % of angiograms there were two arteries in the central sulcus both arising from the posterior parietal trunk or one from the posterior parietal trunk and one from the candelabra group The common occurrence of two vessels in this region may explain the nomenclature used by others who divide the ascending frontal artery complex into four divisions We believe it less confusing to use one term whether one or two arteries are present

On tracing angiograms it was noted that the callosal marginal branches frequently terminated with a sharp downward inclination forming a hook like structure the point of which was directed toward the central sulcus artery On the last 20 brain dissections, the callosal marginal artery was dissected and it was found that this vessel when it arises anteriorly does not cross the marginal ramus and terminates in the area of the pre or postcentral gyrus The pericallosal vessels themselves commonly pass beyond the marginal ramus The sharp hook directed to the central surface artery was found in 67 % of angiograms but may be misleading since other branches of the pericallosal artery may pass upward and terminate in an identical hooklike fashion in other areas

When the common carotid artery is injected at angiography the external branches are also filled The superficial temporal branch of the external carotid artery not infrequently courses posteriorly, directly over the area of the central sulcus artery or the posterior parietal artery and may be confused with these structures For this reason it is especially important to identify the external branches The small size of the central sulcus artery makes it especially liable to concealment by the superimposed surface vessel Conversely a small

Configurations	Brains	%	Angiograms	%
	24	48	39	39
	21	42	47	47
	5	10	14	14
Total	50	100	100	100

Fig. 5. Schematic representation of the various configurations of the central sulcus artery with percentages of occurrence of the different forms.

escaped the attention of neuroradiologists. We had previously had the impression that the most posterior branch of the candelabra group was constant in course and appearance but were unaware of its significance. In the drawing by GREITZ & LINDGREN in ABRAMS textbook there is an unusually prominent central sulcus artery although it is not identified as such. This vessel is not large but was found in all brain specimens and could be identified in all normal angiograms. There may be one or two arteries in the central sulcus, they are located immediately anterior to the posterior parietal artery and are the most posterior branches of the ascending frontal. The course of the central sulcus artery or arteries, differs somewhat from that of the posterior parietal artery which aids in differentiation. The terminal distribution of the posterior parietal artery is usually directed posteriorly while the central sulcus artery has only a slight posterior inclination as it courses upward so that there is an appreciable difference in the direction taken by the two vessels. The vessel or vessels to the central sulcus, as seen on angiograms usually arise at the level of the radiographic Sylvian point and pass upward and slightly posterior to their terminal division. This vessel, when single was seen to arise from a main trunk supplying the posterior parietal and the angular arteries, or the posterior parietal vessel itself, in 18 % of brain dissections and 64 % of angiograms. In 30 % of brain dissections and 17 % of angiograms, the vessel arose as a branch of the candelabra group, in which case the vessel coursed posteriorly over the posterior tip of the operculum before entering the central sulcus and passing



Fig 8 Carotid angiogram from a 37 year-old man with acute stroke and hemiparesis The examination was originally considered normal and the occlusion was not noted until after tracing and applying the template

to the inner line and another posterior parallel to the line from the tuberculum to the point corresponding to the internal occipital protuberance This divides the lateral aspect of the film into four sections The largest and most anterior is the area of the ascending frontal the posterior superior, the area of the posterior parietal The triangle inferior to this is the area of the angular and the trapezoidal area at the base is the area of the temporal vessels An example of the template is given in the schematic drawing of Fig 9

The area of the angular artery is the only one changed from the original template which was objectionable in that the angular and posterior temporal vessels were assigned overlapping areas A further modification may be made using the clino parietal line of CHASE & TAVERAS (1963) instead of estimating the axis of the Sylvian vessels The clino-parietal line in the adult is formed by measuring 9 cm upward from the internal occipital protuberance and drawing a line from this point to the tuberculum sellae Different degrees of magnification may affect the validity of the Chase Taveras system but we have used it on cases examined with both a 30 and 36 inch film target distance with satisfactory results

The area assigned to the ascending frontal complex may be further broken down into three components By measuring anteriorly from the anterior limits of the posterior parietal area 2 5 cm along the outer curved line and drawing a line downward to the midpoint of the Sylvian line a pie shaped area is out-

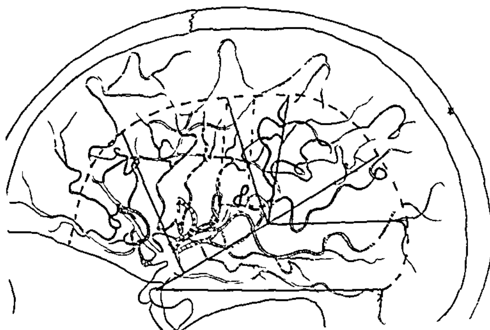


Fig. 7. Schematic drawing representing the vessels in the angiogram of fig. 6. It shows the division of the middle cerebral artery into 6 components, the central sulcus artery being in solid black.

branch occlusion may not be diagnosed if the external vessel is thought to represent an intracerebral one in the same area.

Discussion

The method of applying zones to the termination of the four major branches of the middle cerebral artery previously described (Ring 1962) has been found very helpful in finding small branch occlusions of the posterior parietal angular and posterior temporal branches. Using the same basic pattern, it has been found possible to divide the area assigned to the ascending frontal artery complex into three components, and by so doing additional cases of small branch occlusions have been discovered in cases that had previously been considered normal.

The areas of the four major vessels may be outlined as follows: first, a line is drawn 2.5 cm inside and parallel to the inner table of the skull. A line is drawn from this curve at the point corresponding to the internal occipital protuberance, to the tuberculum sellae. A second line is drawn from the curve down the axis of the Sylvian fissure to the region of the tuberculum sellae. This line, representing the course of the Sylvian vessels, is bisected, and from the midpoint one line is drawn upward parallel to the coronal suture

Artificial lines are a poor substitute for a knowledge of anatomy but we believe that this form of division is very helpful as an anatomical guide and if employed in a few normal cases makes it possible to recognize the subdivisions of the ascending frontal complex as well as the remaining three major branches of the middle cerebral artery A definite angiographic localization of the motor strip by identifying the central sulcus artery should be of considerable benefit to the neurosurgeons Once the normal anatomy was appreciated we have found it possible to identify this artery in many cases with significant vascular displacement from an intracranial mass The greatest use of detailed anatomy however lies in the field of small vessel occlusion for without detailed knowledge of anatomy and meticulous study, small but highly significant occlusions may be missed entirely

Acknowledgement

This investigation was supported by National Institute of Health research grant No 5 ROI HE 05174 06 and Dr Waddington in part by training grant No 5 TI NB 5037 11 from the National Institute of Neurological Diseases and Blindness Some of the patients included in this study were studied under a grant from the John A Hartford Foundation.

SUMMARY

The anatomy of the ascending frontal artery complex is described and a method given of dividing this into three components This has been found of value in identifying the artery to the central sulcus and in recognizing cases of small vessel occlusion

ZUSAMMENFASSUNG

Die Anatomie der ascendierenden Äste der A frontalis und ihre Einteilung in drei Komponenten wird beschrieben Dieser Einteilungsgrund wurde von grossem Wert für die Identifizierung der Arterie des zentralen Sulcus gefunden und um Okklusionen in Kleingefässen festzustellen

RÉSUMÉ

Les auteurs décrivent l anatomie du complexe de l artère frontale ascendante et donnent une méthode pour le diviser en trois composantes Ceci leur a paru intéressant pour identifier l artère de la scissure de Rolando et pour reconnaître les cas d obstruction de petits vaisseaux

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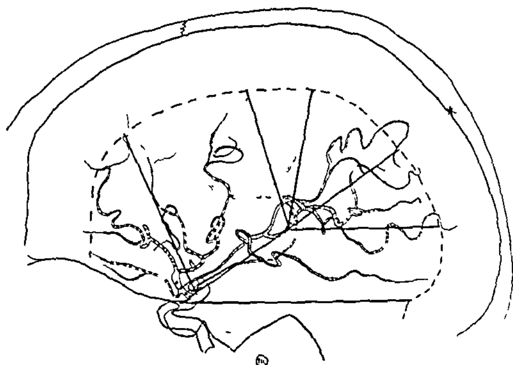


Fig 9 Schematical representation of the angiogram shown in fig 8 with template superimposed omitting the pericallosal vessels Complete absence of vessels to the central sulcus area the vessel simulating this artery being external branch Since the central sulcus artery supplies the motor strip the severe neurological deficit from one small branch occlusion is not surprising

lined that is the area of the central sulcus artery The division between the candelabra group and orbitofrontal vessels is made by measuring the curved line anterior to the central sulcus area to the floor of the anterior fossa, and from the midpoint of this curve drawing a line downward to the dorsum sellae The orbitofrontal vessels lie anterior to this line while the largest group, the candelabra, lie between the orbitofrontal and the central sulcus areas

Since, in identifying the artery to the central sulcus, the central sulcus itself is identified, it is possible to estimate the position of the pre and post central gyri This is outlined in the figure, and is formed by drawing a line 2 5 cm anteriorly along the axis of the operculum as located by the position of the loops of enfolded vessels The anterior portion of this line is connected with the curved line at the most anterior portion of the area assigned to the central sulcus artery The anterior half of this rectangle may be assumed to represent the motor strip while the posterior portion represents the sensory area The upper limits of the gyri are not outlined on this template and extend well above the curved line

Artificial lines are a poor substitute for a knowledge of anatomy but we believe that this form of division is very helpful as an anatomical guide and if employed in a few normal cases makes it possible to recognize the subdivisions of the ascending frontal complex as well as the remaining three major branches of the middle cerebral artery A definite angiographic localization of the motor strip by identifying the central sulcus artery should be of considerable benefit to the neurosurgeons Once the normal anatomy was appreciated we have found it possible to identify this artery in many cases with significant vascular displacement from an intracranial mass The greatest use of detailed anatomy however lies in the field of small vessel occlusion for without detailed knowledge of anatomy and meticulous study small but highly significant occlusions may be missed entirely

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR PROF ERIK LINDGREN), SERAFIMERLASARETTET STOCKHOLM, SWEDEN

GLIOMAS OF THE OPTIC NERVE AND CHIASM

by

G SCHUSTER and G WESTBERG

The necessity of making a correct differential diagnosis of suprasellar tumours has increased during the past few years The treatment of these growths has tended to be conservative because of the high percentage of complications resulting from surgical intervention, at the same time the results of modern radiation therapy improved High dose supervoltage radiation with rotation (KRAMER McKISSACK & CONCANNON 1961) and the administration of isotopes to cystic masses by means of stereotaxis puncture (LEKSELL & LIDÉN 1954 LINDGREN & WESTBERG 1964), are now being employed The difficulties arising in the correct diagnosis of gliomas of the optic nerve and chiasm have also been stressed by earlier authors (DYKE 1941 LINDGREN & DI CHIRO 1951 RUGGIERO 1957 and HOLMAN 1959)

The present study is based on 25 cases of gliomas of the optic nerve and chiasm with or without extension to the hypothalamus all the cases were verified at operation The age at the time of admission varied from 1 to 49 years twenty of the twenty five patients were between 1 and 10 years the remaining five being 14 21 23 44 and 49 years old

Bone changes Different types of changes in the sella turcica were briefly discussed by MARTIN & CUSHING (1923) who described the J shaped hour

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Fig. 1. Large tumour involving both optic nerves and chiasm. Increased intracranial pressure, omega shaped sella due to enlargement of chiasmatic sulcus, both anterior clinoid processes excavated from below.

glass, or omega shaped sella. GOALWIN (1927) discussed the validity of the changes considered pathognomonic of gliomas of the optic chiasm. DEERY (1930) observed them in eleven of his fourteen cases. LYSHOLM & OLIVECRONA (1932) reported this particular type of sella in a case of suprasellar cholesteatoma. LINDGREN & DI CHIRO summarized four different types of sella changes in tumours of this region: (1) 'pressure' sella, (2) cup shaped sella, (3) balloon sella and (4) flattened sella. In one of their cases of optic chiasm glioma, they described the sella configuration as suggestive of omega shape. Changes in the normal shape of the optic canals in different types of intracranial tumours have been exhaustively described in the literature. The most common finding in optic gliomas is a widened optic foramen without decalcification of the walls.

All the present cases were investigated with conventional projections of the skull. Radiologic changes secondary to increased intracranial pressure were present in 12 cases, all of which had dilated lateral ventricles. These cases belonged to the group of large tumours, as mentioned below in connection with the pneumographic changes. The sella configuration was essentially normal in 13 cases. In all the four cases with involvement of only one optic nerve the sella turcica appeared normal in the lateral projection. A definite enlargement of the chiasmatic sulcus, with an upwards concavity giving the sella a configuration that resembled an omega, was present in six cases (Fig. 1). All of these had malignant infiltration of the chiasm. A sella of the type present with increased intracranial pressure was found in five cases. A cup shaped sella was seen in two cases. In one case, the anterior portion of the sella was completely destroyed

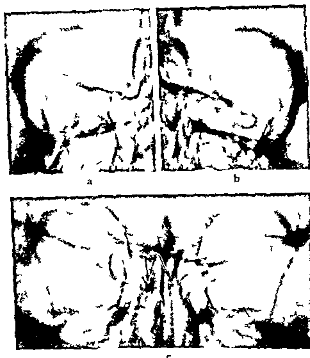


Fig 2 Opt c glioma involving right opt c n rve and ch asm a) Enlarged optic for men without decalcifi at on of the wall b) left s de normal c) A p asymmetric nlargement of the chi smat c sulcus dep ess on of the sella floor (—→) and elevat on of the planum sphenoidale (→→)



F g 3 Larg opt c gl oma nodular supra ellar cal c ficat ons



Fig. 4. From same case as in fig. 2. Encephalography (a) and autotomography with hanging head (b). Antero-inferior part of the 3rd ventricle displaced to the left and slightly elevated.

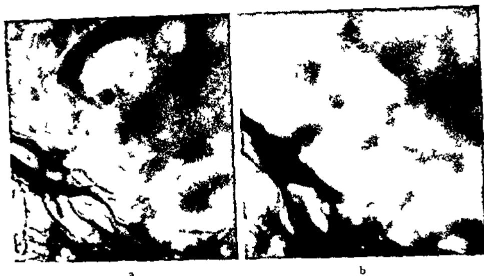
Projections of the optic foramen were obtained in 18 cases, six of these appeared within normal limits, and no intracanalicular extension of the tumour was apparent at operation. Unilateral widening in 9 cases indicated asymmetrical growth of the tumour (Fig. 2). Three neoplasms involved both optic nerves and consequently had enlarged both the optic foramina.

Tumour calcifications. Suprasellar calcifications in optic gliomas have been reported in the literature by several authors. The subject was considered in detail by LINDGREN & DI CHIRO, calcifications were present in three out of nine cases, all of them being included in the present series. They described the calcifications as being of nodular type, with 'small spots rather sporadically and irregularly arranged within a certain area'. On the other hand some authors (MARTIN & CUSHING 1923, VAN BOGAERT 1929, DAVIDOFF & EPSTEIN 1950, and HOLMAN 1959) found no calcified areas at all.

Suprasellar calcifications of the nodular type were present in five of the cases (20%) in the present series. All the calcifications occurred in large tumours and varied from a small, single nodule to several granules spread over an area of 3 5 cm in centre of the tumour.

Pneumography

Pneumography is of the greatest value in the correct diagnosis of growths in the suprasellar region. DAVIDOFF & EPSTEIN described the changes in the chias

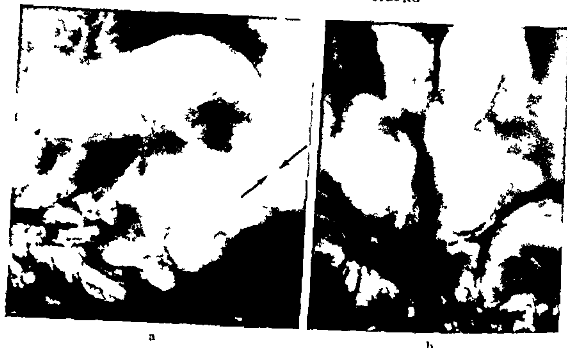


F g 5 Small tumour in olv ıg both nerves and chiasm Tumour well outlined in suprasellar ciste n) and 24 hours later no subarachnoidal air rema ns (b) anterior p rt defo med

matic cistern caused by optic chiasm gliomas as representing a forceps deformity LINDGREN & DI CHIRO stressed the presence of a deformity of the anterior part of the 3rd ventricle and the chiasmatic cistern and the absence of filling of the cisterna laminae terminalis RUGGIERO (1957) found the same changes in his series of three cases

Pneumographic studies were performed in 23 of the cases in the present material, encephalography with examination of the cisterns being carried out in seventeen and ventriculography in four Both methods were used in two cases The two cases studied by ventriculography alone were investigated before encephalography became a routine method The tumour was mainly situated in the orbit in the four gliomas growing only in one optic nerve two of these were intracranially linked through the optic foramen but the enlargement of the nerve was not great enough to be demonstrated by encephalography The remaining 19 cases could be divided into three groups depending on the size of the tumour as evident at operation and pneumography

Group 1 Small tumours not exceeding 1 cm in diameter includes 3 cases in all of which slight separation of the chiasmatic and infundibular recesses was present BULL (1956) reported that the normal distance from the chiasmatic point to the tuberculum sellae varied from 10 to 23 mm as measured in the lateral view The distances were 16 mm 22 mm and 25 mm in the present material



a b

Fig 6 Encephalography Glioma of left optic nerve and chiasm medium sized tumour Third ventricle displaced posteriorly and upwards left ventricle dilated rostral part of the aqueduct dilated (arrows)



Fig 7 Medium sized symmetric tumour bulging into the antero inferior part of the 3rd ventricle between its two recesses inferiorly the pontine cistern delineates the neoplasm (arrow)

(Fig 4) The most important changes were however apparent in the chiasmatic cistern, where an enlarged optic nerve and chiasm were outlined by air (Fig 5) No pathologic changes were demonstrated in the remaining part of the ventricular system and cisterns



Fig 8 Encephalography Very large asymmetric tumour growing also subfrontally

Group 2 Medium tumours not larger than 2 cm in diameter includes 6 cases in all of which lumbar encephalography was performed The chiasmatic and infundibular recesses of the 3rd ventricle were displaced upwards and backwards the tumour in some instances reaching the foramen of Monro without causing significant compression Three cases had dilatation of the lateral ventricles and air filling of part of the 3rd ventricle and the upper part of the aqueduct (Fig 6) The 4th ventricle and the lower part of the aqueduct were never dilated The ventricular dilatation seemed to depend on posterior displacement of the brain stem by the mass and when the stem was compressed against the tentorial notch partial blocking of the aqueduct occurred The chiasmatic cistern was air filled in three cases The postchiasmatic portion of the cistern appeared compressed from above against the diaphragm of the sella the prechiasmatic portion of the cistern being displaced upwards and anteriorly, the tumour also bulged into the anterior portion of the interpeduncular cistern In the remaining three cases, no air filling of these cisterns could be obtained but air in the pontine cistern outlined the posterior inferior border of the tumour (Fig 7)

Group 3 Large tumours more than 3 cm in diameter includes 10 cases All of them had severe hydrocephalus caused by blocking of the foramen of Monro by the mass and partial blocking of the aqueduct due to the posterior displacement of the brain stem In three of the six cases studied by ventriculography no air filling of the 3rd ventricle was obtained In two instances the examination was therefore completed with lumbar encephalography it was then



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(Fig 4) The most important changes were however apparent in the chiasmatic cistern, where an enlarged optic nerve and chiasm were outlined by air (Fig 5) No pathologic changes were demonstrated in the remaining part of the ventricular system and cisterns



Fig 8 Encephalography Very large asymmetric tumour growing also subfrontally

Group 2 Medium tumours not larger than 2 cm in diameter includes 6 cases in all of which lumbar encephalography was performed The chiasmatic and infundibular recesses of the 3rd ventricle were displaced upwards and backwards, the tumour in some instances reaching the foramen of Monro without causing significant compression Three cases had dilatation of the lateral ventricles and air filling of part of the 3rd ventricle and the upper part of the aqueduct (Fig 6) The 4th ventricle and the lower part of the aqueduct were never dilated The ventricular dilatation seemed to depend on posterior displacement of the brain stem by the mass and when the stem was compressed against the tentorial notch partial blocking of the aqueduct occurred The chiasmatic cistern was air filled in three cases The postchiasmatic portion of the cistern appeared compressed from above against the diaphragm of the sella the prechiasmatic portion of the cistern being displaced upwards and anteriorly the tumour also bulged into the anterior portion of the interpeduncular cistern In the remaining three cases no air filling of these cisterns could be obtained but air in the pontine cistern outlined the posterior inferior border of the tumour (Fig 7)

Group 3 Large tumours more than 3 cm in diameter includes 10 cases All of them had severe hydrocephalus caused by blocking of the foramen of Monro by the mass, and partial blocking of the aqueduct due to the posterior displacement of the brain stem In three of the six cases studied by ventriculography no air filling of the 3rd ventricle was obtained In two instances the examination was therefore completed with lumbar encephalography it was then

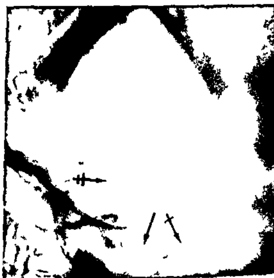


Fig. 9. Large symmetric tumour. Air between tumour and sella entrance (—→); tumour bulges into pontine cistern (+→); cisterna terminalis is air filled and dilated (++→).

possible to demonstrate the 3rd ventricle and to outline the neoplasm in a satisfactory manner. In the remaining four cases, lumbar encephalography was carried out; the entire ventricular system and the cisterns were filled with air. The air filled portion of the 3rd ventricle was situated posterior to the foramen of Monro, and in some cases it was laterally displaced. In addition to marked dilatation of the lateral ventricles, the anterior horns were elevated and flattened from below (Fig. 8). The cisternal changes were valuable in outlining the tumour. Air between the neoplasm and the diaphragma sellae was present in three of the cases in which encephalography was performed (cf. Fig. 9). No air filling of the suprasellar cisterns was obtained in three cases. The interpeduncular cistern was completely obliterated in all cases but it was possible to see the growth bulging into the upper part of the air filled pontine cistern.

Because carotid angiography was performed in only three of the cases, we have no basis for a discussion of the vascular changes that may occur in optic gliomas.

Differential diagnosis

Changes similar to those observed in glioma of the optic nerve and chiasm may also occur in other types of suprasellar tumours. A specific roentgenologic pattern was present in three cases of neurofibromas growing in the orbit; there was marked excavation of the anterior clinoid processes from below, resulting in an omega shaped sella turcica. The orbital fissure and the optic foramen of the involved side were markedly widened, and the bony bridge between them was destroyed. Marked enlargement of the orbit was present in



Fig 10 Large craniopharyngeoma with intrasellar extension Widening of right optic fissure with decalcification of the bridge (arrow) (a) no changes on left side (b)

all instances Encephalography revealed only small changes in the suprasellar cisterns The findings in the neurofibromas thus differed from those in the optic gliomas of the present series in which extensive skeletal changes were always associated with significant intracranial extension of the tumour

In a series of 30 cases of craniopharyngeoma no changes in the optic foramen the orbital fissure or the intervening bony bridge were present when the tumour was situated in the suprasellar region However in those situated also within the sella, definite enlargement of the orbital fissure was apparent (Fig 10) Decalcification and in some cases complete destruction of the bridge occurred No enlargement of the optic foramen was observed The encephalographic appearances of the craniopharyngeomas situated in the suprasellar region differed depending on their relationship to the chiasm When they were at a site posterior to the chiasm which occurred in most of the cases, the 3rd ventricle was displaced upwards and the tumour bulged into its inferior border The craniopharyngeomas located in the prechiasmatic area generally pushed the 3rd ventricle mainly backwards without separating the antero inferior recesses

The most frequent suprasellar expanding lesion the upwards growing adenoma, produces on rare occasions changes similar to those seen in optic gliomas Analysis of the skeletal changes and the deformity of cisterns and the ventricular system make it possible however to differentiate between pituitary adenoma and optic glioma

In our few cases of suprasellar meningeoma specific diagnosis was possible when typical meningeoma bone formation was present Narrowing of the

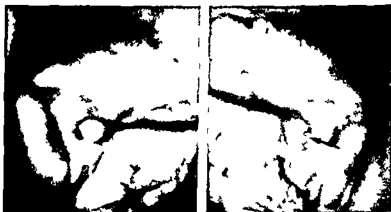


Fig 11 Meningeoma of left optic foramen with a small exostosis

foramen occurred in one case in which the tumour was growing in the optic foramen (Fig 11) When calcifications were present, they were more compactly and uniformly arranged than in optic gliomas (LINDGREN & DI CHIRO) Encephalography often revealed the free border of the mass surrounded by cisternal air and backward displacement of the anterior part of the 3rd ventricle

Conclusions

Skeletal changes are a common finding in glioma of the optic nerve and chiasm Widening of the optic foramen without cortical destruction is a sign of involvement of the intracanalicular portion of the optic nerve, as occurred in two thirds of the cases In almost half the number of cases no sella changes were observed When they did occur, the most common type of sella was the so called J shaped, or omega shaped sella Complete absence of skeletal changes does not, however, exclude an optic glioma A careful encephalographic study, with filling of the suprasellar cistern, is therefore of the greatest value in the diagnosis of gliomas of the optic nerve and chiasm Tumours without skeletal changes may be accurately diagnosed only by these means Even in cases of large tumours it has always been possible to fill the 3rd ventricle by performing lumbar encephalography

Enlargement of the chiasmatic sulcus may occur in chronic obstructive hydrocephalus due to pressure from the enlarged optic recess, thus giving the sella turcica an omega like appearance The anterior clinoid processes are then, however, not excavated from below

SUMMARY

A series of 25 cases of glioma of the optic nerve and chiasm is presented Roentgen examination of the skull and encephalography with filling of the cisterns were found to be the most effective way of demonstrating site and size of tumour The differentiation of these gliomas from other types of suprasellar expanding lesions is discussed

ZUSAMMENFASSUNG

Eine Serie von 25 Fallen mit Gliom des Sehnerven und des Chiasmas wird vorgelegt Es zeigte sich dass die gewohnliche Rontgenuntersuchung und die Encephalographie am besten geeignet sind um die Grosse und die Lage des Tumors zu ermitteln Es wird auf die Faktoren hingewiesen die eine Unterscheidung von anderen suprasellaren Tumoren ermoglichen

RÉSUMÉ

Présentation de 25 cas de gliome du nerf optique et du chiasma L examen radiographique du crâne et l en ephalographie avec cisternographie sont les méthodes les plus utiles pour determiner le siège et les dimensions de la tumeur Les auteurs étudient le diagnostic différentiel de ces gliomes avec d autres types de lésions expansives suprasellaires

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MECHANISM IN INDIRECT ARTERIAL DISPLACEMENTS OVER CEREBRAL CONVEXITIES ACCOMPANYING CEREBRAL MASS LESIONS

by

HAROLD LEHRER

The usual arrangement of arteries in the body in such organs as the spleen [a]nd kidney for instance implies that arteries arise from a more or less central [hi]lus and proceed as they subdivide approximately in a radial fashion to the [p]eriphery Should a space occupying lesion be present within such organs [th]e arterial radiants will in many instances be displaced around the borders of [t]he mass so that they will be tangential to it and form a kind of envelope [t]hat gives a direct indication of the size of the lesion (The term envelope is [u]sed here in its everyday sense as well as by analogy to its use in mathematics [t]o describe a family of curves which superimpose upon a curve which is a [c]ommon tangent)

This kind of arterial displacement as illustrated in Fig 1 will be referred to as direct or tangential arterial displacement in contradistinction to the indirect or non tangential vascular diplacements to be described below

If the tumor is markedly infiltrating or vascular tangential displacements will either not occur or will be obscured An infiltrating tumor presents no

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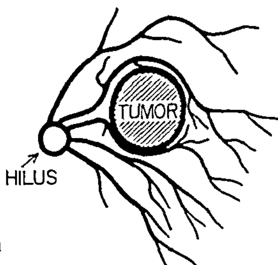


Fig 1 Arteries radiating from a central hilus showing direct or tangential displacement and forming an envelope about a tumor

surfaces for reflection of adjacent vessels and tends to enmesh them, while a markedly vascular tumor may obscure the arterial 'radiants' in its vicinity

The brain differs from other major organs in the body since its major arterial supply does not follow a centrifugal pattern from a central hilus to the periphery but its larger branches instead proceed from the circle of Willis over the complex surfaces of the brain The arteries remain superficial (the arteries over the insula follow the infoldings of the surface) giving rise to many small perforating arteries which proceed in a centripetal direction to nourish brain parenchyma Compared to the vessels at the surface, the radiating arteries that are sufficiently large to be demonstrated on customary angiography as, for example, the lenticulo striate arteries, are considerably smaller in size

Therefore, whether cerebral mass lesions are on the surface or not, displacements of major arteries, where present, must take place on the brain surfaces because that is where the major arteries are In cases where the mass is at the surface, these displacements may be tangential or directly analogous to Fig 1, as they are reflected about a superficial lesion But with non surface lesions, local arterial displacements at the surface will be secondary not to the tumor itself but to volume changes produced by it and therefore these displacements will be non tangential or indirect Volume changes with intracerebral mass lesions are often amplified because of concomitant cerebral edema (TAVERAS & WOOD 1964)

Direct displacements are seen in falx and parasagittal meningiomas which typically are outlined by the pericallosal and callosomarginal arteries Similar tangential displacements are seen with other meningiomas (Fig 2) Indeed, meningiomas are the tumors that show direct arterial displacements to the



Fig 2 Subf ontal meningioma outlined (white arrows) by d ect displacement of branches of the pericallosal artery Straightened ascending m ddle cerebral convexity branch (black arrows) rep esenting an ind rect displacement due to the same tumor



Fig 3 Straightening of the anterior convexity arteries due to an underlying frontal mass le sion (anterior pairs of arrows) which has pushed the sylvian triangle downward and backward (posterior vertical arrows)



F g 4 Stra ghtened convex ty vessels due to a large underlying f onto-parietal mass lesion Compare with fig 5

best advantage since they generally are superficially located and are almost always non infiltrating Further they are usually not accompanied by signifi cant cerebral edema and their angiographic vascularity is such that adjacent cerebral arteries are not obscured

Gliomas since they tend to be infiltrating may not be as favorably demon

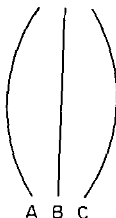


Fig 5



Fig 6

Fig 5 Meridians of longitude effect produced by indirect displacement of arteries around an underlying lesion Line B represents the central tumor meridian

Fig 6 a) Normal gyri with intervening sulcus b) The sulci become shallower and flatter from an underlying brain swelling



Fig 7 Slice of brain post mortem showing a vessel lying on the surface of the insula free in the subarachnoid space except for being fixed at intervals (arrows) by perforating vessels Some local arachnoid thickenings are present

strated by direct arterial displacements, even when they are superficial since when such infiltration is present there is no definite tumor surface about which to reflect vessels and these may also be enmeshed in the tumor However, in favorable instances superficial gliomas may cause direct arterial displacements comparable to those with meningiomas

The majority of gliomas produce arterial displacements at the surface by an indirect mechanism, dependent upon volume changes rather than direct reflection about the tumor As already noted, these tumors, as well as the majority of metastatic tumors, tend to be accompanied by considerable cerebral edema acting to amplify volume changes

Characteristically, in these indirect displacements arteries lose their usual undulation and become straightened or curved with a single curvature (Figs 3 and 4) The curvature tends to be gentler than with direct displacements, i e the radius of curvature is larger, and the convexity of the curved arteries may be in opposite directions at the boundaries of the area of increased spherical



Fig 8 Stretch ng of surface cerebral arteries between points of relati e fixa on caused by locally increased volume Compare with fig 6

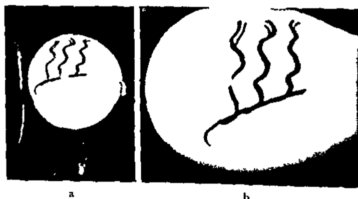


Fig 9) Partly expa ided balloon Parallel inked lines inserted to pro v de a model of convexity arter es b) B lloon further expanded The inked lines rema n parallel

volume like meridians of longitude (Fig 5) The central tumor meridian has also been called axis artery (KRICHEFF & TAVERAS 1963)

An explanation has been proposed for these indirect arterial displacements based on tensions from adjacent gyri pressing on the artery between them like two balloons (TAVERAS & WOOD) producing straightening when the tensions are equal and curvature when the adjacent gyri exert unequal tension This ex planation is probably incorrect because surface cerebral vessels usually run over the gyri as well as between them so that they could only be squeezed between gyri intermittently in their course Also when there is local swelling due to increased volume sulci between the swollen gyri flatten and become more shallow (Fig 6) Thus the vessels in these shallow sulci become elevated and stretched with regard to the underlying brain rather than squeezed

Cerebral arteries normally contain elastic tissue (BLACKWOOD 1963) and are somewhat redundant as they run in the subarachnoid space When these vessels are examined in brain slices at post mortem the arteries are movable by forceps manipulation more at some points than at others Perhaps the

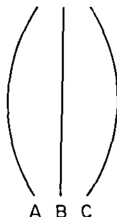


Fig. 5

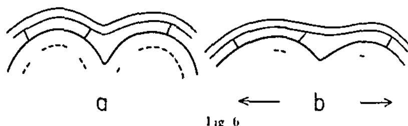


Fig. 6

Fig. 5. Meridians of longitude effect produced by indirect displacement of arteries around an underlying lesion. Line B represents the central tumor meridian.

Fig. 6. a) Normal gyri with intervening sulcus. b) The sulci become shallower and flatter from an underlying brain swelling.



Fig. 7. Slice of brain post mortem showing a vessel lying on the surface of the insula free in the subarachnoid space except for being fixed at intervals (arrows) by perforating vessels. Some local arachnoid thickenings are present.

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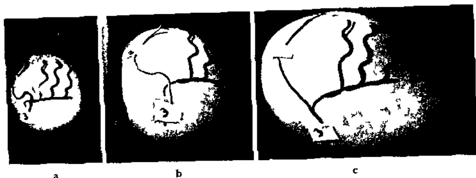


Fig 11 Direct comparison of the two models Partly expanded a) further expanded b) and still further expanded balloon c) There is marked straightening of the elastic band while the inked arteries representing uniform expansion remain curved

The previous statements can be demonstrated by a model using a toy balloon If several undulating but approximately parallel lines are drawn on the surface of the half expanded balloon with a felt laundry marking pen to represent ascending cerebral arteries and the balloon is then fully expanded the arteries remain parallel and undulating although each artery becomes wider This would be in analogy with the change to be expected in cerebral arteries if they were uniformly stretched along pial attachments by an underlying tumor (Fig 9)

On the other hand if elastic rubber bands are fixed at several points on the balloon and the balloon is only moderately increased in volume the rubber bands rapidly lose their redundancy and straighten and then stretch Ultimately a great circle is followed (Fig 10) For further emphasis of the difference in behavior both models can be combined (Fig 11)

Thus in frontal and parietal areas where a roughly spherical surface is produced by a local increase in volume brought about by the intracerebral lesion with its accompanying edema the behavior of cerebral arteries on the surface is felt to be like the rubber bands of the balloon model Paths like meridians of longitude are produced but these indirect arterial displacements while secondary to the tumor should not be taken as outlining the tumor proper

In temporal and posterior temporal temperoparietal lesions the tumor volumes are not quite so sphere like but more closely approximate cylindrical or saddle shaped surfaces Thus geodesics are not spherical but the arterial displacements that are observed and commonly are known as draping are also felt to follow the shortest line path for these surfaces in approximately a similar fashion



Fig. 10. a) Redundant elastic rubber *bands have* been fixed at intervals to provide a model of convexity arteries. b) The balloon has been *slightly* expanded. The arteries already show straightening. c) With only moderate expansion of the *balloon there is* marked straightening of the arteries.

general fixation is due to pia arachnoid more or less loosely binding the vessel *to the surface*, with the *tethering effect of* the small perforating vessels (KLOSOVSKII 1963) possibly *representing* points of greater fixation.

As the brain swells locally, the fixation points spread (Fig. 7), and the vessel between them loses some *of its* undulation since it still must connect these points (Fig. 8). As *the* swelling progresses, the arteries at the surface will *assume the shortest* distance they can between their points of fixation, ignoring the effect of locally *increased blood* supply which tends to increase vascular tortuosity. This effect *is* usually of second order and longer term, and so usually *is not* prominent with deep gliomas.

Thus, in essence, the elastic vessel is caused to take the shortest possible path between its points *of fixation*. In Euclidean, or plane, geometry the shortest *distance* between two points is a *straight line*. On any other surface, the shortest curve between *two points is* characteristic for that surface and is known as the *geodesic line* for that surface (HILBERT & COHN VOSSEN 1952). On a spherical *surface*, like the earth, *geometry is non-Euclidean*, and the shortest distance between two points or *geodesic line* is the great circle passing through the two points.

Since a space occupying *lesion with its* surrounding edema tends to produce an increase in local volume, *arteries* on the cerebral surface, tending to take the shortest path they can, therefore follow the geodesics of the surface produced by the increased local volume. *Since in* the frontal and parietal regions this volume is more or less spherical, the surface arteries more or less approximate great circles (Figs 3, 4, and 5).

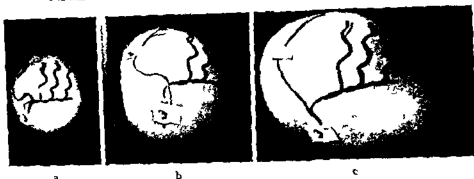


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SUMMARY

Arterial displacements over the cerebral convexities occurring with intracranial mass lesions are divided into two main types (1) direct or tangential where the tumor is outlined as the arteries enveloping the lesions and thus indicating the true size of the tumor (2) indirect or non tangential secondary to volume changes produced by the tumor and not indicating the true size of the tumor A theory and a model are proposed to explain indirect displacements based on the tendency of partially fixed vessels to follow geodesic lines

ZUSAMMENFASSUNG

Die bei intrakraniellen Tumoren vorkommenden Verschiebungen der Arterien uber die Gehirnkonvexitat werden in zwei Haupttypen eingeteilt (1) direkte oder tangentiale wo die Arterien den Tumor abgrenzen und dadurch die exakte Tumorgrosse hervorbringen und (2) indirekte oder nicht tangentiale sekundar zu den von dem Tumor verursachten Volumenveranderungen wobei die genaue Tumorgrosse nicht hervorgeht Ein Modell wird vorgeschlagen um die indirekten Verschiebungen zu erklaren wobei man davon ausgeht dass die partiell fixierten Gefasse geodatische Linien folgen

RÉSUMÉ

Les déplacements d artères à la convexité cérébrale qui surviennent en cas de tumeur intracranienne sont divisés en deux grands types (1) direct ou tangentiel quand la tumeur est cernée par les artères qui indiquent ainsi les dimensions exactes de la tumeur (2) indirect ou non tangentiel secondaire aux modifications de volume produites par la tumeur et n indiquant pas les vraies dimensions de la tumeur L auteur propose une théorie et une maquette expliquant les déplacement indirects basées sur la tendance des vaisseaux partiellement fixés à suivre les lignes géodésiques

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MENINGEAL BRANCHES OF THE OPHTHALMIC ARTERY

by

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Both the internal and external carotid arteries distribute branches to the dural meninges, i.e. the convexity dura, the dura of the skull base, the tentorium and the falx. Interest has recently been focused on the blood supply from the internal carotid artery. BERNASCONI & CASSINARI (1956) first described the radiologic appearances of the tentorial branch of the internal carotid artery. FRUGONI et coll. (1960) have also mentioned them, and they were subjected to thorough anatomical investigation by SCHNURER & STATTIN (1963). STATTIN (1961) briefly described two meningeal branches of the ophthalmic artery, and in anatomical textbooks more or less standardized descriptions of the meningeal branches of the artery may be found. The details of these descriptions do not always, however, coincide with the findings at angiography. The author has therefore made a study of the anatomy of the dural branches of the ophthalmic artery by means of serial angiography in normal and pathologic material.

As regards the normal anatomy, earlier investigations have indicated that the ophthalmic artery arises from a parasellar portion of the siphon and passes

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Fig. 1. Normal case. a) Lateral projection. The recurrent meningeal artery (→) runs from the proximal part of the intraorbital ophthalmic artery back into the middle fossa and branches out. b) Intraorbital projection. The recurrent artery and its branches supply both the anterior and medial aspects of the middle fossa (→).

through the optic canal accompanied by the optic nerve. In anomalous cases, the artery may enter the orbit through the sphenoid fissure.

After entering the orbit the ophthalmic artery gives off a very small branch, or branches, called the recurrent meningeal artery because it runs back into the middle fossa through the lateral part of the orbital fissure (STATTIN 1961). This artery may anastomose with the middle meningeal artery. An anastomosis may also occur through the meningo orbital foramen between branches of the lacrimal artery and those of the middle meningeal artery; this latter channel is not consistently present. Hence, both these channels, i.e. vessels passing through the orbital fissure and the meningo orbital foramen, contribute to the supply of the anterior part of the dura of the middle fossa and form anastomoses between the ophthalmic artery and the middle meningeal artery or the dural branches of the internal carotid artery.

The frontal extension of the ophthalmic artery gives off two or three branches towards the ethmoid cells: the posterior ethmoidal artery (or arteries) and the anterior ethmoidal artery. Small branches arise from the former and supply the basal dura of the frontal region.

The anterior ethmoidal passes through the orbitocranial canal and reaches the anterior fossa; it gives off small branches, the so called anterior meningeal arteries. In some cases, the anterior meningeal artery is so large as to play a major part in supplying the dura of the frontal convexity but in others the branches of the middle meningeal artery extend to the dura of the frontal region.

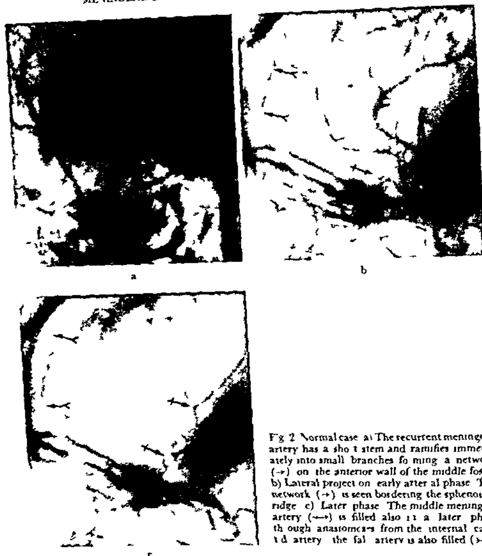


Fig 2 Normal case a) The recurrent meningeal artery has a short stem and ramifies immediately into small branches forming a network (→) on the anterior wall of the middle fossa b) Lateral projection early arterial phase The network (→) is seen bordering the sphenoidal ridge c) Later phase The middle meningeal artery (⟶) is filled also in a later phase through anastomoses from the internal carotid artery the falx artery is also filled (>→)

As far as the author has been able to ascertain no meningeal supply of the falx from the ophthalmic artery has been described

Present material One hundred serial angiographic examinations considered as normal have been studied In addition fifty frontal and middle fossa meningiomas ten intracranial temporal lobe tumours and fifty cases of internal carotid occlusion were analysed



Fig. 1. Normal case. a) Lateral projection. The recurrent meningeal artery (→) runs from the proximal part of the intraorbital ophthalmic artery back into the middle fossa and branches out. b) Intraorbital projection. The recurrent artery and its branches supply both the anterior and medial aspects of the middle fossa (→).

through the optic canal accompanied by the optic nerve. In anomalous cases, the artery may enter the orbit through the sphenoid fissure.

After entering the orbit the ophthalmic artery gives off a very small branch, or branches, called the recurrent meningeal artery because it runs back into the middle fossa through the lateral part of the orbital fissure (STATTIN 1961). This artery may anastomose with the middle meningeal artery. An anastomosis may also occur through the meningo orbital foramen between branches of the lacrimal artery and those of the middle meningeal artery; this latter channel is not consistently present. Hence, both these channels, i.e. vessels passing through the orbital fissure and the meningo orbital foramen, contribute to the supply of the anterior part of the dura of the middle fossa and form anastomoses between the ophthalmic artery and the middle meningeal artery or the dural branches of the internal carotid artery.

The frontal extension of the ophthalmic artery gives off two or three branches towards the ethmoid cells: the posterior ethmoidal artery (or arteries) and the anterior ethmoidal artery. Small branches arise from the former and supply the basal dura of the frontal region.

The anterior ethmoidal passes through the orbitocranial canal and reaches the anterior fossa; it gives off small branches, the so called anterior meningeal arteries. In some cases, the anterior meningeal artery is so large as to play a major part in supplying the dura of the frontal convexity but in others the branches of the middle meningeal artery extend to the dura of the frontal



Fig 2 Normal case a) The recurrent meningeal artery has a short stem and ramifies immediately into small branches forming a network (→) on the anterior wall of the middle fossa b) Lateral projection early arterial phase The network (→) is seen bordering the sphenoidal ridge c) Later phase The middle meningeal artery (↠) is filled also in a later phase through anastomoses from the internal carotid artery the falx artery is also filled (↣)

As far as the author has been able to ascertain no meningeal supply of the falx from the ophthalmic artery has been described

Present material One hundred serial angiographic examinations considered as normal have been studied In addition fifty frontal and middle fossa meningiomas ten intracranial temporal lobe tumours and fifty cases of internal carotid occlusion were analysed



Fig 3 Normal case Contrast medium injection into the internal carotid artery late arterial and early venous phase Small anterior meningeal artery running in a groove in the frontal bone (In the frontal projection it did not reach the midline)

Results

Normal anatomy An intraorbital projection facilitates the identification of the recurrent meningeal artery This artery usually runs laterally and ramifies into small branches along the anterior wall of the middle fossa Sometimes several branches of the recurrent artery run in a medial direction and give off branches to the medial aspect of the middle fossa (Fig 1b) The recurrent meningeal artery arises at a sharp angle from the proximal portion of the ophthalmic artery, as is clearly seen in the lateral view (Fig 1a)

It is not easy angiographically to differentiate between the recurrent meningeal artery and the lacrimal branch of the ophthalmic artery, as both anastomose with the middle meningeal artery on the anterior wall of the middle fossa If an artery, before its entrance into the middle fossa, is seen to run a somewhat long intraorbital course (Fig 6) it will probably be the artery passing through the meningo orbital foramen, and hence the lacrimal artery It should also be remembered that the lacrimal branch usually has a single immediate connection with the middle meningeal artery, whereas the recurrent meningeal artery ramifies into a network before anastomosing with other middle meningeal branches

The meningeal branches of the posterior ethmoidal artery are rarely seen in normal cases because these branches are quite small and superimposed by the ethmoidal bony structure The subtraction technique may prove useful in demonstrating these branches When evident, they are usually dilated, particularly in cerebral arterial occlusion or olfactory groove meningeoma

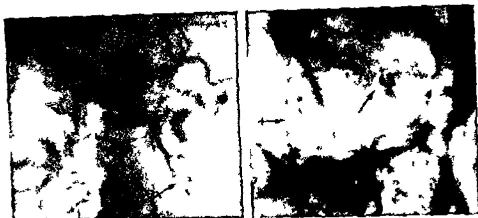


Fig 4 Occlusion of internal carotid artery due to thrombosis Carotid siphon filled from a branch of middle meningeal artery (↔) via the widened short stem of the recurrent meningeal artery and the dilated ophthalmic artery other collaterals from the maxillary artery to the ophthalmic artery (→) are also present

The term anterior meningeal arteries should be reserved for the arteries arising from the anterior ethmoidal artery and passing over the dura of the convexity The anterior meningeal arteries supply the dura of the frontal convexity in a variable distribution (Figs 3 and 7)

The anterior ethmoidal artery also supplies a branch to the falx This branch which has not previously been described may be called the anterior falx artery It enters between the two layers of the dura at the base of the skull, usually over the lamina cribiformis The anterior falx artery can be demonstrated on both sides but either side may be dominant in the blood supply of the falx (Figs 2 7 and 10)

It may be difficult to differentiate angiographically between the most anterior meningeal artery and the falx artery It certainly appears that if an artery lies close to the midline and has a straight course in an a p view it should be the falx artery On the other hand an artery that follows a zig zag course in an a p view and hence departs from the midline should not be taken for the falx artery even if it runs along the inner table of the frontal bone in the lateral projection The anterior meningeal artery may occasionally be seen to follow a groove in the inner table (Fig 3) In normal as well as pathologic cases the anterior falx artery of each side in the lateral projection is seen to arise from the distal portion of the anterior ethmoidal artery and after crossing over the cribiform plate to approach the frontal pole and run parallel with the inner table of the bone never crossing the inner table In the a p view the proximal part of the artery rises until it reaches the midline

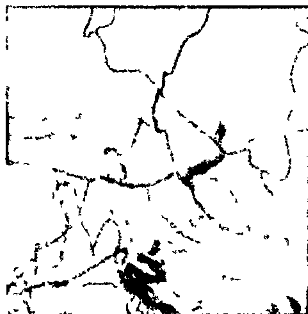


Fig 5 Thrombosis of the internal carotid artery No collaterals through the recurrent meningeal branch hence the ophthalmic artery is dilated also distal to the origin of this branch there are several connections with branches of the maxillary artery



Fig 6 Case of severe head injury Angiography of the common carotid artery intraorbital projection Flow interrupted at the carotid siphon branches of the middle meningeal artery (←→) are connected to one branch of the ophthalmic artery which extends laterally in the orbit this vessel forms the lacrimal meningeal branch of the artery (→)

Appearences of the meningeal branches of the ophthalmic artery in cerebrovascular occlusive disease and intracranial tumour Good opportunities for studying the meningeal branches of the ophthalmic artery, and their connections with the external and internal carotid arteries, are present in cerebrovascular occlusive disease, since the meningeal branches and anastomosing vascular channels then become dilated When the occlusive change involves the internal carotid artery proximal to the ophthalmic artery, the meningeal branches of the ophthalmic artery and their connections with the middle meningeal artery are utilized as bypasses from the external carotid artery to the cerebral blood vessels

Four types of anastomoses to the ophthalmic artery from the middle meningeal artery are (1) through the recurrent meningeal branch or/and the lacrimal meningeal branch, (2) through the meningeal twigs of the posterior ethmoidal artery, (3) through the anterior meningeal branches of the anterior ethmoidal artery, and (4) through the anterior falx branch of the anterior ethmoidal artery

Among these four collaterals the first type is the most common and was noted by MARX in 1949 The second type of collaterals occurs less frequently The other two types of meningeal connections are more frequently observed



Fig Case of occlusion of the anterior cerebral artery (The middle cerebral artery was filled in an earlier phase) Contrast medium is seen *to remain in* the internal carotid artery the anterior meningeal arteries (→) and the anterior falx artery (→→ *are* clearly visible The artery running close to the midline may be identified as the anterior falx artery the others being anterior meningeal arteries

but are not large enough to fill the internal carotid artery through the ophthalmic artery Sometimes two or three collaterals to the ophthalmic artery including vessels other than the ophthalmic meningeal anastomoses are observed simultaneously in the same case Their differentiation may then be difficult

If the sphenoidal branches of the middle meningeal artery are large and only the proximal part of the ophthalmic artery is dilated which is best seen in the lateral view (Fig 4) it may be concluded that the collateral circulation is established through the recurrent meningeal branch Then the short stem of the latter artery is usually dilated In the intraorbital projection this recurrent branch does not cross above the sphenoidal ridge The course of the lacrimal branch is similar to that of the recurrent branch but has a longer extension laterally with fewer anastomoses with the middle meningeal artery (Fig 6) The dilated meningeal branches of the anterior and posterior ethmoidal arteries can sometimes be clearly demonstrated when there is occlusion



Fig 8 Case of meningeoma arising from the medial third of the sphenoidal ridge The ophthalmic artery is markedly dilated but becomes normal in diameter after giving off the recurrent meningeal artery (→) the attachment of the tumor may be precisely localized by the pathologic vessels arising from the recurrent artery

of the anterior cerebral artery It is not possible to determine whether these branches supply a collateral circulation to the brain (Fig 7)

In many cases of internal carotid occlusion, the anterior meningeal branches and the anterior falx artery are filled through their anastomoses with the middle meningeal branches, i e from the external carotid artery Both channels are then more or less dilated When the occlusive process involves the circulation in the circle of Willis, a rete mirabile can be used to anastomose the external circulation with the intracerebral blood flow This type of channel has been studied anatomically by VAN DER EECKEN & ADAMS (1953), and its radiologic appearances have been described by WEIDNER et coll (1965)

In the surgical treatment of meningeoma, a preoperative knowledge of the vascular supply of the tumor is of great value Information regarding the tumor attachment, which is usually indicated as the point of entrance of feeding meningeal vessels, is of special interest to the surgeon An examination of the meningeal arteries is therefore particularly necessary in meningeoma As to the vascular distribution of the ophthalmic artery, its meningeal branches participate in supplying three main groups of meningeoma, i e sphenoidal ridge, frontobasal, and anterior falx meningioma A common angiographic finding in these tumours is widening of the ophthalmic artery (Figs 8, 9 and 10)



Fig. 9. Case of frontobasal meningeoma. *Typical branching of the posterior ethmoidal artery* supplying an olfactory groove meningeoma; the attachment of the tumor is clearly seen.

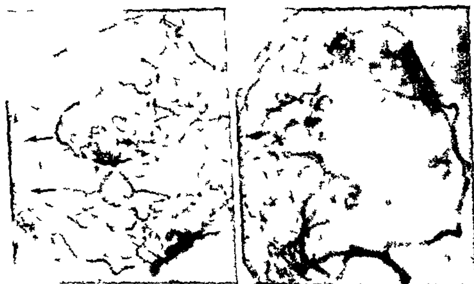


Fig. 10. Case of right-sided meningeoma of the anterior part of the falx partly supplied by the falx artery. Angiography of the right internal carotid artery revealed the limits of the tumor; the falx artery is only faintly outlined from this side.

The sphenoidal meningeomas are supplied from the arteries of the middle fossa dura and from the recurrent *meningeal* artery, as well as from the lacrimal artery (Fig. 8). A submentovertical projection may be helpful in the analysis of the blood supply to this region.

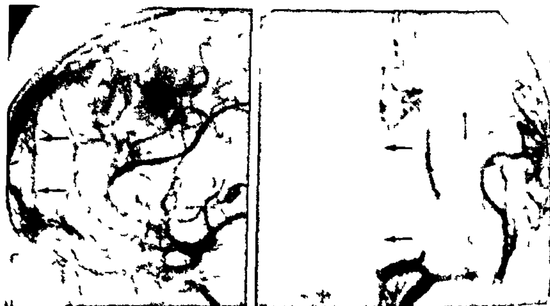


Fig. 11. Same case as the one illustrated in fig. 10. Angiography of the left internal carotid artery. The dilated left anterior falx artery is filled, indicating that the blood supply of the tumor is through this artery and the contralateral ophthalmic artery.

The frontobasal meningeoma is supplied from the posterior ethmoidal artery (Fig. 9). As mentioned above, this artery gives off numerous short branches to the posterior cribiform plate.

When a meningeoma develops on the anterior convexity, the middle meningeal or anterior meningeal arteries, or both, may be attached to the base of the tumor.

The meningeomas of the anterior part of the falx obtain their blood supply from the arteries of the convexity dura as well as from the anterior falx artery. The latter may be filled by internal carotid angiography, sometimes from both sides (Fig. 10). In the case of a falx meningeoma, bilateral angiography must be performed to demonstrate the blood supply of the tumor, since either side may predominate in supplying the blood to the falx.

SUMMARY

The anatomy of the meningeal branches of the ophthalmic artery has been studied angiographically in normal cases, in those with occlusive cerebrovascular disease and in those with meningeomas within the meningeal area supplied by the ophthalmic artery.

ZUSAMMENFASSUNG

Die Anatomie der meningealen Äste der Arteria ophthalmica wurde angiographisch studiert sowohl in normalen Fällen als auch in Fällen mit stenosierenden Gefässveränderungen oder Meningeomen im Bereich der A. ophthalmica.

RÉSUMÉ

L anatomie des branches méningées de l artère ophtalmique a été étudiée angiographiquement dans des cas normaux dans des cas d obstruction de vaisseaux cérébraux et dans des cas de méningiome de la région meningée par l artère ophtalmique

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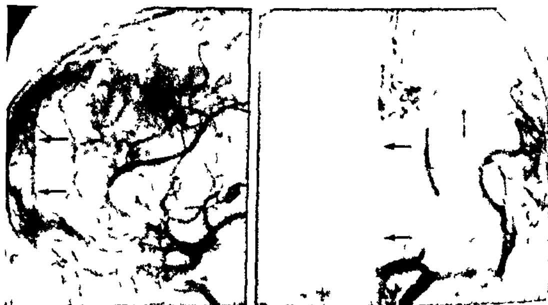


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CINELYMPHORADIOGRAPHY AND CORONARY VENOUS RADIOGRAPHY

by

A. CELIS, R. CICERO, G. RIOS, H. DEL CASTILLO, H. MARQUEZ, D. MIJANGOS and F. CANO

The morphology, distribution and progress of lymph towards the myocardial and subepicardial collectors were discussed in a previous paper (CELIS et coll. 1966) in which a new indirect technique of cardiac lymphangiography was described.

The literature on the dynamics of lymph within the thorax was reviewed and only the cineradiographic works of MALEK et coll. (1960), POMERANTZ et coll. (1963) and LACHAPELLE et coll. (1964) on the dynamics of lymph flow through the right thoracic duct have so far been gone through. These authors concluded that the lymphatic flow is modified by respiration, cough, Valsalva's maneuver, diaphragmatic movement, arterial pulsations and morphine. Studies on the peristaltic waves of the duct and on its emptying were also surveyed and considered.

This paper summarizes the findings obtained in cineradiography and established from colour motion films in studies on the dynamics of the lymph flow in the heart and mediastinum in relation to the normal pattern of the cardiac lymphatic network and the anatomy of the mediastinal lymph nodes.

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Fig 1 The anterior cardiac lymphatic collectors and the mediastinal nodes wer clearly seen 80 minutes after the inject on of contrast medium into the septum

Material and Methods All the experiments were performed in 18 living dogs pentobarbital intravenous anesthesia with endotracheal cannulation was employed

Posterolateral left thoracotomy was performed the pericardial sac was opened and the heart held with the left hand A needle connected to a French catheter was introduced directly into the myocardium and fixed by means of a simple silk suture in order to avoid changing its position The thorax was closed the other end of the catheter being left free for the injection of contrast medium

The cineradiographic films were obtained with a 9 image intensifier, a 35 mm reflex camera and a 500 mA roentgen apparatus using the factors film speed 16 squares per second 68 kV and 0 14 mAs The injection of contrast medium was made through the catheter and its progress within the myocardium was followed on a television monitor cine films were obtained at intervals The medium was injected at a rate of 0 5 ml/min until a dosage of 4 0 ml had been reached Continuous EKG tracings were recorded during the procedure Roentgenograms of the chest were obtained for seven days

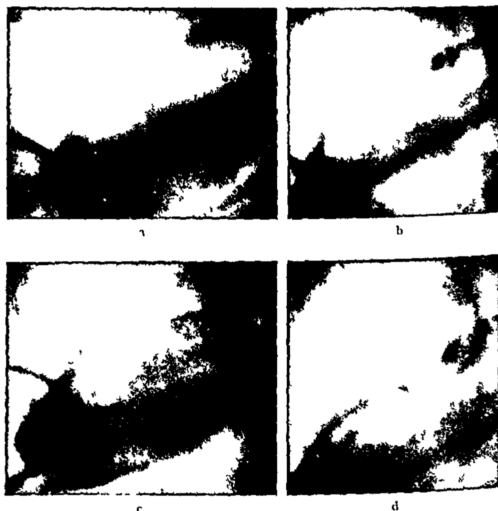


Fig. 2. *Cineradiographic* sequence after injection of contrast medium into the anterior aspect of the heart. *Appearance of the cardiac node* at 10 min after the injection (a). At 18 min (b), 36 min (c) and at 45 min (d) the lymphatic collectors became filled and the first *group of mediastinal* nodes were outlined; the myocardial spot increased in size in relation to the *amount of medium* injected.

following the *experiment in order* to observe the fate of the medium injected. In three cases, in order to obtain better anatomic detail the heart was isolated and examined with films of finer grain and higher contrast.

The lymphatics of the myocardium were stained with the thorax open. Following median sternotomy the pericardial sac was *opened* and fixed to the thoracic wall, the heart being punctured as previously mentioned and Evans blue injected into the myocardium. The progress of the dye was observed directly in the heart and in the lymphatic mediastinal nodes. Colour cine films were obtained at proper intervals.



Fig 3 Ci er d og aph c sequence at inject on of contrast medium into the int rvent icula septum a) At 12 m n the cardiac ode was contrast f lled a d the lymphat c card ac collectors follow ng the anterior co onary vessel al o became ev dent b) At 20 min and c) at 40 min the s ptum became is bl as a h lf moon shaped image and the card ac lymphat c collectors al o appea ed d) At 60 mi the mediast nal nodes were seen near the apex of the ight half of thora

Results

The morphologic features of the lymphatic vessels of the anterior and posterior aspects of the heart were verified and the drainage of lymph from the inter ventricular septum through the subepicardial collectors accompanying the left descending coronary vessels could be demonstrated (Fig 1) The contrast medium was injected into the anterior area of the septum, the posterior area not being explored



Fig. 4 Persistence of the contrast medium six days after the intramyocardiac injection. The spot of contrast medium had vanished and the medium followed the margins of the heart and persisted along the course of the veins; mediastinal nodes were also seen.

A small quantity of medium was immediately visible in the films and increased progressively in size and shape in relation to the amount injected. The cardiac lymph nodes were first visible, and 9 to 10 minutes later the lymphatic collectors became visible, as if they had been filled in a retrograde direction.

According to the amount of contrast medium injected and the time elapsed, the contrast medium in the myocardium adopted different shapes, outlining the apex and the ventricular walls. When the contrast medium was injected into the septum, the 'spot' of contrast medium appeared as a half moon and moved synchronously with the heart beats. By following the movement of the 'spot' of medium on the television monitor it was possible to observe the cardiac contractility with great accuracy.

When 35 minutes had elapsed, the mediastinal nodes became visible, different groups of nodes could be seen, one in the middle of the mediastinum and another close to the apex of the left side of the thorax. After 55 minutes, the collectors of the right lymph duct became visible up to the termination of the duct at the jugulo subclavian angle or the innominate vein (Figs 2 and 3). Cinelymphangiography and radiography of the cases revealed no connections with the left thoracic duct nor anastomosis between the two lymphatic systemic networks. Cardiac lymphangiography in one of the cases disclosed, however, a mediastinal collector connecting with both systems.

Observation of the lymphatic flow with the thorax open revealed that the

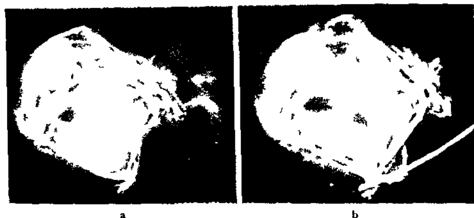


Fig 5 Heart isolated six days after the intramyocardiac injection of contrast medium a) The medium could be seen to persist (cf fig 4 b) The coronary sinus was catheterized and contrast filled

subepicardial lymph vessels appeared almost immediately after the Evans blue solution had been injected The myocardial spot of medium was visible after 4 min and later (at 15 to 25 min) the pre aortic and mediastinal nodes became visible finally (at 40 min) it was possible to observe the termination of the right lymphatic duct at the jugulo subclavian angle The dye stained the lymph nodes intensely and made them easily discernible in the mediastinal areolar tissue

On cineradiography and serial radiography at 2 3 4 and 96 hours after the injection it became possible to see double contour images corresponding to the initial myocardial spot which became thicker and converged towards the atrio ventricular sulcus and there ended in a trunk, the opening of this trunk was sometimes visible at the right atrium (Fig 4) As these images could possibly correspond to the coronary venous system an attempt was made to judge this possibility by removing a heart producing this typical image and injecting the coronary vessels with contrast medium The once contrast loaded coronary veins were found to reproduce the parallel images (Figs 5 and 6) Another experiment consisted in the ligation of the coronary vein lymphangiography revealed an interruption at the level of the ligature

It was observed in one animal in which cardiac arrest was induced by a toxic dose of pentobarbital that the contrast medium progressed through the lymphatic vessels and the cardiac node became visible even though the heart had stopped



Fig 6 Heart isolated seven days after the intramyocardiac injection using fine grain film The fine pattern corresponds to the distribution of the myocardiac fibers The contrast medium followed the course of the coronary veins

Electrocardiograms revealed the appearance of ventricular extrasystoles after the contrast injection in the anterior, lateral or posterior ventricular walls, but normal sinus rhythm was re established after a few minutes with injection into the septum Extrasystoles, subendocardial ischemia and alteration of the interventricular conduction were observed, disturbances that disappeared between 35 minutes and a few hours after the injection All the animals used in this study survived and were in normal condition after the experiments

Discussion

The radiologic and histologic studies, with diffusion of the contrast medium injected into the myocardium, led to the following results The interstitial spaces (Fig 6) were rendered visible against the negative images of the fascicles of the myocardial fibers, the lymphatic cardiac system could be demonstrated, and the coronary veins were also outlined with the contrast medium

Some differences in the dynamics of the cardiac lymph flow appeared according to whether dye or a radiographic contrast medium was used (Fig 7) The cardiac lymph node actually acts as a filter and offers resistance to the lymph flow from the heart, so that the contrast medium stops at this node and fills it completely, this accounting for its early visibility in the roentgenograms On the other hand, when the myocardium was injected with Evans blue, the

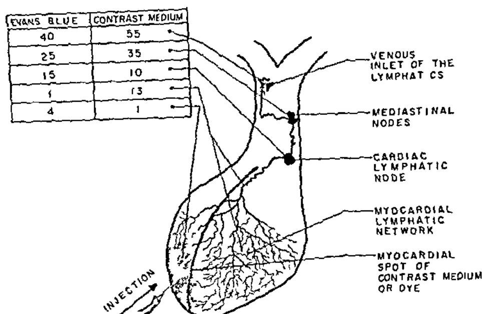


Fig 7 Time of appearance of dye and contrast medium Summary of the dynamical data the time elapsed being given in minutes The numbers represent the averages obtained from all the experiments

subepicardiac network became visible immediately because the dye diffuses rapidly and only later can the lymph nodes be seen This is contrary to what was observed in the roentgenograms where the nodes appeared first and the lymphatic vessels later

Peristaltic waves were never observed in the lymphatic vessels in the colour film or in the cineradiographic films The lymph flow is slower on the left side than in the thoracic duct depending on stages determined by the lymph nodes present in the mediastinum The progress of the lymph flow appears to be due only to pressure changes and not to the contractility of the lymphatic vessels For this reason the flow may be altered by changes in the intrathoracic pressure, secondary to cough Valsalva's maneuver and the like as described by POMERANTZ et coll (1963) in their report on the thoracic duct

Observations made on the days following injection of the contrast medium into the myocardium indicated that the dye follows exactly the venous coronary vessels a fact which can be verified by obtaining a correlation between the images obtained after injection of contrast medium into the coronary sinus In both instances the contrast medium follows the auriculo ventricular sulcus and the transverse course of the coronary sinus at its junction with the right

atrium The contrast loading observed would seem to correspond to the medium in the perivenous lymphatic network, and may be explained by a probable late filling due to the obstacle caused by the lymph nodes to the lymph flow

SAPPEY (1874), DRINKER (1939), and YOFFEY & COURTICE (1956), in their classic papers, do not mention any lymphatic drainage of this region It may nevertheless be concluded that the contrast medium follows the perivenous lymphatic vessels, as in Fig 4, in which the medium is seen closely to follow the course of the coronary veins

The radiographic demonstration of the cardiac venous system depends at present on the possibility of catheterization of the coronary sinus through the right atrium This method does not produce adequate anatomical details and is not free of risks (BING et coll 1947) GORDON et coll (1950), in a series of 1 200 angiographic examinations, identified the coronary sinus on two occasions TORI (1951) demonstrated the coronary sinus and its branches by means of cardiac catheterization CAMPITI et coll (1955) determined the morphologic features of the coronary veins in two human cadavers by injecting the heart with contrast medium The same authors, in 25 % of their cineangiocardiographic examinations, demonstrated the coronary sinus by reflux of the medium from the auricle The coronary sinus was filled with the contrast medium and received a reflux from the right atrium Some sort of congenital or acquired pathologic condition (in 88 %) with right sided hypertension was present in most of the cases in which filling occurred Reflux of the medium from the right atrium into the coronary sinus may also be observed in dilated hearts, this finding is in agreement with those of HELLERSTEIN & ORBISON (1951) who observed an enlargement of the coronary sinus opening in cases of heart failure with dilated cardiac chambers

Practical methods in angiography mainly consist in obtaining a static or dynamic filling according to observations made in roentgenograms with respect to morphologic features The authors feel that the method described should be useful in the study of some disturbances, such as myocardial infarction and congenital and acquired diseases of the heart

Conclusions

The lymphatic drainage of the septum of the heart could be demonstrated through the lymphatic collectors following the left anterior coronary vessels Two or three mediastinal nodes receive the cardiac lymph flow before draining into the right lymphatic duct

Dye and contrast medium, injected into the myocardium were rapidly absorbed and drained into the cardiac lymph node, which acted as a filter, so

that backward repletion of the cardiac lymph vessels was accomplished The precise chronology of the lymph flow of the heart was studied

With the intramyocardial injection of contrast medium the venous and the coronary sinus walls may be outlined by filling of the perivenous lymphatic network The method may be regarded suitable for the study of the veins of the heart in different conditions

SUMMARY

The findings obtained by cineradiography and colour films in 18 dogs in an investigation of the dynamics of the lymph flow in the heart and mediastinum are reported The normal pattern of the cardiac lymphatic network and the anatomy of the mediastinal lymph nodes are described

ZUSAMMENFASSUNG

Die Dynamik des Lymphflusses im Herzen und im Mediastinum wurde mittels Kineradiographie und mit Hilfe von Farbfilmen an 18 Hunden studiert Die normale Anatomie des Lymphgefässnetzes des Herzens und die Anatomie der mediastinalen Lymphknoten werden beschrieben

RÉSUMÉ

Les auteurs présentent les résultats d une étude dynamique de la *circulation lymphatique* de coeur et du médiastin faite sur 18 chiens par cinéradiographie et par films en couleurs Ils décrivent la disposition normale du réseau lymphatique cardiaque et l anatomie des ganglions lymphatiques du médiastin

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FROM THE DEPARTMENT OF PATHOLOGY KAROLINSKA SJUKHUSET STOCKHOLM, SWEDEN

ANASTOMOSES BETWEEN EXTRACARDIAC VESSELS AND CORONARY ARTERIES — II — VIA INTERNAL MAMMARY ARTERIES

Post mortem angiographic study

by

ANDERS MOBERG

Two systemic vascular beds are potential sources of extracardial anastomoses to the coronary arteries the bronchial arteries and the internal mammary arteries The extracardial anastomoses via the bronchial arteries have been described in a previous paper (MOBERG) Unlike anastomoses via the bronchial arteries the anastomoses via the internal mammary arteries have received considerable attention in the literature since ligation of the internal mammary arteries has been employed for the surgical treatment of ischaemic heart disease

The operation was originally described by FIESCHI (1942) who performed it for the first time on a human subject in 1939 At operation the two internal mammary arteries are ligated in the second costal interspace The idea behind the operation is to direct the blood flow to the pericardiophrenic arteries These vessels originate from the first part of internal mammary arteries and then run parallel to the phrenic nerve down to the diaphragm The arteries give off branches to adjacent structures including the pericardium

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Patients treated by this method have sometimes shown subjective improvement (BATTEZZATI et coll 1955, GLOVER et coll 1957) but scarcely any objective signs, such as improvement in the electrocardiograms Few reports, however, deal with the anatomical background and demonstration of the anastomotic vessels

In studies on human cadavers, FIESCHI ligated the internal mammary arteries in the second costal interspace and at the origin from the subclavian artery Injection of the isolated part of the internal mammary artery filled the vasa vasorum of the aorta and pulmonary artery BATTEZZATI et coll (1955) repeated the experiments and demonstrated filling of vessels in the myocardium and epicardial fat Unfortunately, these two articles lack details about the number of subjects injected, and age, sex and injection pressure Only FIESCHI referred to coronary atheromatosis and stated that the subjects were 'young and without cardiac disease'

The purpose of this study was to find out the extent of the anastomoses between the internal mammary artery system and the coronary arteries and correlate the results with a similar study on the extent of extracardial anastomoses via the bronchial arteries

Anatomical background The internal mammary artery arises from the subclavian artery behind the first rib or the clavicle It passes caudally along the sternal border between the parietal pleura and the intercostal muscles In addition to the pericardiophrenic artery mentioned previously, the internal mammary artery gives branches to the thymic region, adjacent muscles and bones and directly to the pericardium The intercostal arteries communicate with the internal mammary artery, and sometimes one of the bronchial arteries emanates from the artery Via retrosternal branches the two mammary arteries anastomose with each other

In the majority of subjects no pericardial adhesions are present The only possibility for blood from extracardiac sources to reach the coronary arteries is (1) to the pericardial reflexion and then (2) either via the vasa vasorum of the aorta or via the atrial arteries A detailed description of the anatomy of these vessels was given in part I (MOBERG 1967)

Material and Methods

Case series The investigation was carried out on post mortem material and the time between death and autopsy varied from 8 hours to 5 days, during which period the bodies were refrigerated

Fifty six specimens were examined It was originally intended to obtain

Table 1

Age and percentage of intact lumen in coronary arteries (mean values)

Age in years	Sex and number of cases		Percentage of intact lumen of coronary artery		
	Males (30)	Females (19)	Right	Left descending	Left circumflex
31 to 40	1	2	34	35	30
41 to 50		5 (1)	40 (51)	39 (45)	45 (4[illegible])
51 to 60	9 (1)	2	28 (43)	22 (28)	31 (43)
61 to 70	8	3	23	22	31
71 to 80	10 (1)	7 (1)	25 (29)	23 ([illegible]5)	28 ([illegible]9)
81 to 90	2		9	19	1

In order to estimate the degree of stenosis transverse sections of the arteries were used In atheromatosis the internal elastic lamina can be destroyed or changes be present in the media It was therefore necessary to have the external elastic lamina as a reference This means that the expression degree of stenosis also includes the cross section area of the media The method therefore gives low values i e values apparently expressing higher degrees of stenosis than is actually the case The results however agree with those published by LOBER (1953)

Figures in parantheses indicate the four specimens mentioned in the text in which ventricular coronary arteries were filled

to be excluded e g cases in which recent thoracic surgery had been performed

Six specimens had to be discarded because of reflux of contrast medium into the ascending aorta left ventricle or coronary arteries An additional specimen had to be excluded due to a technical error in the preparation of the histologic specimens Thus 49 subjects were included in the investigation and 26 of them died from extra thoracic non vascular diseases The main diagnoses for the remaining 23 subjects were generalized atheromatosis and heart failure (8), vascular diseases of the brain (6) myocardial infarction (4), pulmonary embolism (2) valvular heart disease (1) ruptured aortic aneurysm (1) and pulmonary tuberculosis (1) In addition to the two patients with pulmonary embolism, and one subject with cirrhosis of the liver, five more patients had small pulmonary emboli and an additional patient had a cirrhotic liver Two patients had carcinoma of the pancreas Pericardial adhesions were not observed in any instance

The age distribution and the degree of coronary stenosis as evaluated by the method described below are given in Table 1 The heart weight and myocardial changes are given in Table 2 A complete list of our case records with all pertinent data can be obtained from the author

Injection technique and material Before opening the body cavities a small incision was made on the right side parallel to and in the interspace between

Table 2

Heart weights and myocardial changes

Weight	Recent infarction	Recent and old infarctions	Old infarction	Scattered fibrosis	Myocardium without major changes	Total
300	1			1	7 (2)[1]	9 (2)
300–399			2	2	13	17
400–499	1	1	2		8 (1)	12 (1)
500–		2	1	2	6 (1)	11 (1)
Total	2	3	5	5	34 (4)	49 (4)

[1] Figures in parantheses indicate the four specimens mentioned in the text in which ventricular coronary arteries were filled

the second and third ribs The internal mammary artery was identified and injected through a polythene catheter In eight of fifty six subjects, injection was not possbile in this location, and in six patients injection was performed after another incision in the interspace between the third and fourth ribs Injection was made in the interspace between the second and third ribs on the left side in the remaining two patients, because of previous right sided thoracoplasty in one and perforation of the right internal mammary artery by the catheter in the other

The injection material was an aqueous 25 % microcrystalline barium sulphate suspension (Micropaque[R]) With the pressure retort described by LJUNGQVIST (1963) the injection pressure was kept at a maximum of 130 mm Hg

Preliminary trials were made to establish the amount of contrast medium needed for appropriate contrast filling The internal mammary arteries anastomose with each other, and with the intercostal arteries, and as a consequence contrast material could always be identified in the aorta In an early phase of the study, 150 to 250 ml of contrast material was used but, with one exception, the specimens had to be discarded because contrast material appeared in the ascending aorta and the left ventricle, and the coronary arteries were partially filled via the sinuses of Valsalva It was therefore decided to use about 50 ml of the contrast suspension, but even so six specimens had to be excluded from the series on account of filling of the coronary arteries via the aorta

Radiographic procedure After completion of the injection, radiograms were made of the specimens using 72 kV and 12 mA and Gevaert Osray films without





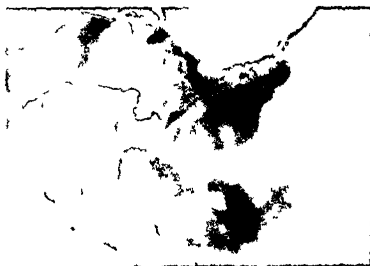
Fig 1 Anteroposterior view internal mammary artery injection Contrast filling of minor atrial vessels in the right atrium

intensifying screens and an exposure time that varied between 0 5 and 3 0 sec The film focus distance was 1 5 m The projections used were an anteroposterior view of chest organs with the pericardium intact a lateral view of the heart pericardium and mediastinum with the lungs removed and an anteroposterior view of the isolated heart The right and left sides of the heart were then separated along the interventricular septum and radiograms were obtained of the sides separately

Method of correlation with atheromatosis To find out whether a correlation exists between the extent of extracardial anastomoses and the severity of coronary atheromatosis the degree of stenosis of the coronary arteries was determined according to the method described by LOBER (1953) (Table 1) The method was described in detail in a previous paper (MOBERG 1967)

Results

Vessels in the pericardium were filled with contrast medium in all the 49 specimens The vessels were not only visible in the anterior part but quite often in the dorsal and diaphragmatic portions of the pericardium as well In one instance the anteroposterior radiogram of the chest organs was under exposed and could not be used In the remaining 48 specimens arteries with a course corresponding to that of the pericardiophrenic artery were clearly visible in 33 and not visible in 2 An artery probably the pericardiophrenic artery but possibly a pericardial vessel was seen in the remaining 13 speci



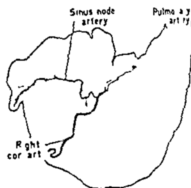


Fig 2 Anteroposterior view of opened right side of heart internal mammary artery injection Right coronary artery contrast filled via the sinus node artery

mens In 6 out of these 18 specimens the bronchial arteries were filled within the lungs Identification of the pericardiophrenic and bronchial arteries, however, was difficult since the radiograms were not primarily exposed for this purpose

The radiograms of the heart were examined for the presence of contrast medium in the vessels These vessels were classified as (1) small atrial vessels usually situated around the ostia of the veins (*pulmonary*, *inferior or superior vena cava*) (see Fig 1), and (2) ventricular coronary arteries (right, left descending and left circumflex branch) (see Figs 2 and 3) In 30 specimens (*out of the total of 49 investigated*) no filling was obtained Minor atrial vessels filled in 15 cases, and ventricular coronary arteries in 4 cases, in the latter of which the right coronary artery was filled in one case and the circumflex branch of the left coronary artery in 3 cases

In the three specimens in which the circumflex branch of the left coronary artery was filled, the left atrial arteries were the afferent vessel In one heart, the right coronary artery was filled via the sinus node artery (ramus ostii cavae superioris) These four hearts were the only ones in which contrast material reached the ventricular level There was no apparent reason — age, sex, or degree of coronary stenosis (Table 1), heart weight and myocardial changes (Table 2), bronchial artery filling, or interval between death and autopsy — why anastomoses to the ventricular level could be demonstrated in only these particular hearts

Despite careful examination of the radiograms *it could not* be stated that the mediastinal vessels had an unusual course *or origin in the* specimens in





Fig 3 Anteroposterior view of opened left side of heart internal mammary artery injection Circumflex branch of left coronary artery contrast filled via a left atrial artery massive calcification of the mitral ring

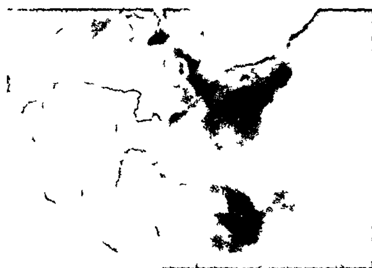
which the ventricular coronary arteries were filled It turned out however, that the contrast filling appeared to take place via the lower dorsal part of the pericardium i e the regions where the venae cavae and pulmonary veins enter

Minor arteries in the atrial walls were filled with contrast medium in 15 specimens When these were compared with those in which no vessels within the heart had been filled, there was no correlation with age coronary stenosis or myocardial changes There was a slight male over representation 12 of 15 instead of the figures that could be expected from the total material, 10 of 15 The difference and the material however, are too small to allow conclusions The interval between death and autopsy was less than in the rest of the material a fact speaking against the time lapse as a promoting factor in demonstrating anastomoses post mortem

Discussion

The contrast suspension was injected into one of the internal mammary arteries It is well known that the two mammary arteries anastomose with each other and a preliminary study (ARVIDSSON & MOBERG 1966) showed that there was no advantage in injecting both arteries Furthermore the filling of the pericardiophrenic artery and vessels within the pericardium and the fact that six subjects had to be excluded due to contrast material in the ascending aorta left ventricle or coronary arteries indicate that the method of injection filled the internal mammary artery system

Extracardial anastomoses via the bronchial arteries existed in every subject



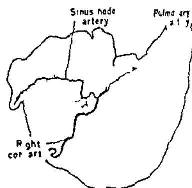


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examined (MOBERG 1967). Extracardial anastomoses via the internal mammary artery cannot be discussed without taking the bronchial arteries into account, it is known since the description by HALLER (1747) that the bronchial arteries can have an anomalous origin, i.e. from the internal mammary artery. In a detailed article based on dissection studies on human cadavers CAULDWELL et coll. (1948) found that the left bronchial arteries more often originated from the subclavian artery than did the bronchial arteries to the right lung (only 3 of 150 cadavers). In the present material, bronchial arteries within the lungs were filled with contrast material in 6 of 48 specimens (13 %). Since the lungs were radiographed in one plane only, this figure might be too small. The injection technique resulted in partial contrast filling of the aorta. A possibility would thus be that the bronchial arteries were filled the ordinary way, i.e. from the aorta. From the radiograms this seems possible to exclude in 5 specimens. The bronchial arterial contrast filling was slight in 3 of the 6 specimens, only one or possibly two arteries in one lobe. Ventricular coronary arteries were not filled in any of these six specimens. In the present material it therefore seems justified to exclude filling of the bronchial arteries as a promoting factor in filling vessels within the heart. This conclusion, of course, is apparently incompatible with the results presented in part I of this paper (MOBERG 1967). In that investigation, however, it was the aim to fill the bronchial arterial system with contrast medium. In the present study the bronchial arteries were filled, most likely, via anastomoses from the internal mammary artery and there must be a great difference in both the pressure and the volume of contrast medium in the bronchial arteries.

In four of forty nine subjects, ventricular coronary arteries were filled with contrast medium. There was no difference, however, in the over all degree of stenosing coronary atheromatosis between these four subjects and the rest of the material. There was, then, no evidence that coronary atheromatosis favours the formation of extracardial anastomoses via the internal mammary artery. Whether, on the other hand, coronary atheromatosis promotes enlargement of already existing anastomoses cannot be evaluated from the present material.

In a previous report of extracardial anastomoses via the bronchial arteries, ventricular coronary arteries were filled with contrast material in 31 of 37 specimens and minor atrial vessels alone in 6 specimens. It was possible to prove that artefacts were involved in all these six cases. In the present material, injected via the internal mammary artery, minor vessels of the same type were demonstrated in 15 of 49 specimens. The internal mammary artery was easier to inject than the bronchial arteries and there were no

comparable artefacts in the present material It therefore seems reasonable to assume that the intercostal arteries communicating with the internal mammary arteries are a major factor accounting for the poor demonstration of vessels within the heart

Ligation of the internal mammary arteries as a surgical procedure has received some experimental support from investigations in dogs BLAIR et coll (1957 1960) found that 6 months after operation the blood supply via extracardiac sources increased from 1 ml/min to 9 6 ml/min Similar results were reported by GLOVER et coll (1957) who also found a higher survival rate for dogs in which the mammary arteries and a coronary artery were ligated than for dogs in which only a coronary artery was ligated These results could not be verified by SABISTON & BLALOCK (1958) who performed the same experiment By injecting India ink into the internal mammary artery GRIFFIN et coll (1957) could demonstrate filling of minute epicardial vessels *The experimental results are thus somewhat contradictory* although pointing to some extracardiac blood supply via the internal mammary artery In the light of the present investigations it seems obvious that a discussion of extracardial anastomoses to the coronary arteries is incomplete without taking the *bronchial arteries into account Furthermore since it is known that in dogs* large anastomoses exist between the bronchial arteries and the internal mammary arteries (BERRY et coll 1931 HORINE & WARNER 1932) the experimental results in dogs cannot allow conclusions about the source of the extracardiac blood supply

SUMMARY

Extracardial anastomoses via the internal mammary artery were investigated by post mortem angiography Ventricular coronary arteries were filled in 4 of 49 hearts and in an additional 15 specimens filling was noted in minor atrial arteries The results are discussed in relation to internal mammary artery ligation and results obtained in a parallel study of extracardial coronary anastomoses after injections into the bronchial arteries It appears that anastomoses to the heart are far more common via the bronchial than via the internal mammary arteries

ZUSAMMENFASSUNG

Extracardiale Anastomosen über die Art. mammaria int wurden post mortem mittelst *Angiographie untersucht Die* Koronararterien der Ventrikel wurden in 4 von 49 Herzen gefüllt und in 15 weiteren Autopsie Präparaten konnte eine Füllung der kleineren Atriumarterien beobachtet werden Die Resultate werden mit Hinsicht auf die operative Unterbindung der Art mammaria int und die in einer Parallelstudie erhaltenen extracardialen Koronaranastomosen nach Injektion in die Bronchialarterien besprochen Es scheint als ob diese *Anastomosen* zum Herzen über die Bronchialarterien weit häufiger sind als über die Aa mammariae int

RÉSUMÉ

L'auteur a étudié par angiographie post mortem les anastomoses extracardiaques des artères coronaires qui se font par l'artère mammaire interne. Les artères coronaires ventriculaires ont été injectées dans quatre coeurs sur 49 et de petites artères auriculaires ont été injectées dans 15 autres cas. L'auteur examine ces résultats en vue de l'opération de ligature des artères mammaires internes et les compare aux résultats d'une étude parallèle des anastomoses extracardiaques des coronaires après injection dans les artères bronchiques. Il conclut que les anastomoses allant au coeur se font beaucoup plus souvent par les artères bronchiques que par les artères mammaires internes.

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THE MITRAL ORIFICE

by

INGER BROLIN

The demands for detailed preoperative evaluation of the appearance and function of the mitral orifice have increased This is because nowadays a differentiated surgical technique is used which takes into account the extent and degree of severity of the pathologic changes The object of the present survey is to demonstrate the roentgenologic possibilities of evaluating the mitral orifice First an account will be given however, of the normal anatomy of the mitral orifice and of the pathologic changes that arise in mitral stenosis and incompetence

Normal and pathologic anatomy

The anatomical position of the mitral orifice in relation to the thorax has been studied by e g VIRCHOW 1913 WALMSLEY 1958 and KNESE 1963 If the mitral plane is envisaged as a surface bordered by the annulus the ventricular side of this surface is directed towards the left forwards and obliquely downwards in the erect position There is however a wide range of variations and the conditions in post mortem studies cannot be directly applied to angiocardiographic examinations However on broad lines the mitral plane seems to

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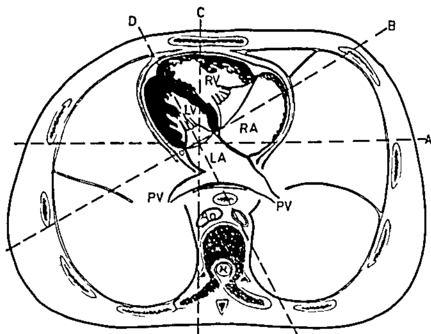


Fig. 1. Cross section through the thorax at the level of the 7th thoracic vertebra, lower surface of section. Sketch after HAFFERT (1957). The broken lines show the direction of the beam in different projections: A — lateral projection, B — right anterior oblique (r.a.o.) projection, C — frontal projection, D — left anterior oblique (l.a.o.) projection. LA — left atrium, LV — left ventricle, RA — right atrium, RV — right ventricle, PV — pulmonary veins, Ao — aorta.

form an angle of about 30° with the frontal plane and of 70° to 90° with the horizontal plane (Fig. 1).

The mitral orifice consists of the following four components:

1. *Annulus fibrosus*, the atrioventricular ring, forms part of the fibromuscular skeleton of the heart. It is chiefly the lateral part of the ring that contracts during ventricular systole. The contracture contributes to the closure of the mitral orifice (SMITH et coll. 1950, NICHOLS & BAILEY 1959, FRATER & ELLIS 1961, DAVIS & KINMONTH 1963).

2. *Leaflets*. The anteromedial (aortic or septal) leaflet is more triangular than the posterolateral (ventricular or mural) leaflet, which is almost quadrangular. The distance from the free margin to the annulus is greatest for the anteromedial leaflet, whereas the margin of attachment to the annulus is greatest for the posterolateral leaflet (RUSTED et coll. 1952, CHIECHI et coll. 1956, NICHOLS & BAILEY). Since the lateral part of the annulus undergoes greater contraction, the true apposition of the two free margins is facilitated during systole. It is

not only the margins which come into contact but on closure of the leaflets about a third of the surfaces facing the atrium are pressed against each other (BROCK 1952 VAN DER SPUY 1958) The basal parts of the leaflets bulge towards the atrium like a parachute (FRATER & ELLIS LEVY & EDWARDS 1962)

The two leaflets are joined in the commissures which thus lie anterolaterally and posteromedially Accessory leaflets may be present in the commissures Since the posterolateral leaflets is more or less deeply cleft it is difficult to distinguish between a deeply cleft leaflet and an accessory one This explains why the incidence figures for the occurrence of accessory leaflets vary (HARKEN et coll 1952 RUSTED et coll CHIECHI et coll)

3 *Chordae tendineae* These join the leaflets to the papillary muscles or myocardium Their attachment is such that the chordae run from each papillary muscle to the corresponding half of the two leaflets There are three kinds of chordae Those of the first order are numerous delicate chordae directly attached to the margins of the leaflets and are responsible for their accurate apposition (BROCK RUSTED et coll CHIECHI et coll FRATER & ELLIS) Those of the second order are coarser than the aforementioned and are attached to the ventricular aspect of the leaflets Three to six millimeters from the margin they pass directly into the tissue of the leaflet (SOKOLOFF et coll 1950) These chordae are the most important ones for preventing inversion of the leaflets into the atrium during ventricular systole (FRATER & ELLIS) Short chordae of the third order pass from the ventricular wall to the basal parts of the leaflet They are missing on the anteromedial leaflet whose ventricular surface partly forms the lateral wall of the outflow tract of the ventricle (RUSTED et coll CHIECHI et coll)

4 *Capillary muscles* These lie directly below the corresponding commissure (RUSTED et coll 1951) In 60 to 70% of cases the posterior papillary muscle is multi headed The corresponding figure for the anterior group is 20 to 30% (RUSTED et coll CHIECHI et coll) Since the margin of the leaflet makes no large movements (RUSHMER et coll 1956) and the distance between the apex and the atrioventricular plane does not much increase in systole (VON HAYEK 1959 DAVIS & KINMONTH) only an inappreciable contraction is needed for the papillary muscles to stretch the chordae and prevent eversion of the leaflets

In stenosis the pathologic changes in the four components of the mitral orifice may be as follows

1 Sclerosis of the annulus fibrosus with impaired mobility may be a component of mitral stenosis (HARKEN et coll 1951)

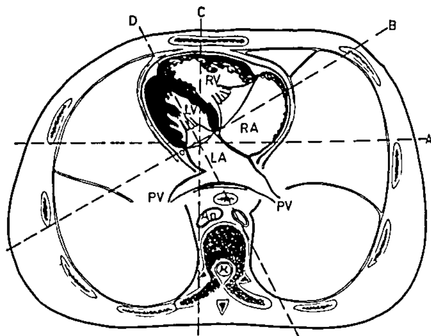


Fig 1 Cross section through the thorax at the level of the 7th thoracic vertebra lower surface section Sketch after HAFFERL (1957) The broken lines show the direction of the beam in different projections A — lateral projection B — right anterior oblique (r a o) projection C — frontal projection D left anterior oblique (l a o) projection LA — left atrium LV — left ventricle RA — right atrium RV — right ventricle PV — pulmonary veins Ao — aorta

form an angle of about 30° with the frontal plane and of 70° to 90° with the horizontal plane (Fig 1)

The mitral orifice consists of the following four components

1 *Annulus fibrosus* the atrioventricular ring forms part of the fibromuscular skeleton of the heart It is chiefly the lateral part of the ring that contracts during ventricular systole The contracture contributes to the closure of the mitral orifice (SMITH et coll 1950, NICHOLS & BAILEY 1959 FRATER & ELLIS 1961, DAVIS & KINMONTH 1963)

2 *Leaflets* The anteromedial (aortic or septal) leaflet is more triangular than the posterolateral (ventricular or mural) leaflet, which is almost quadrangular The distance from the free margin to the annulus is greatest for the anteromedial leaflet, whereas the margin of attachment to the annulus is greatest for the posterolateral leaflet (RUSTED et coll 1952, CHIECHI et coll 1956, NICHOLS & BAILEY) Since the lateral part of the annulus undergoes greater contraction, the true apposition of the two free margins is facilitated during systole It is

each group of chordae runs to both the anteromedial and the posterolateral leaflet fusion causes reduced mobility and the leaflets may approach each other to such a marked degree that a funnel shaped structure arises, even without fusion of the leaflet margins Involvement of third order chordae may cause fusion of the posterolateral leaflet with the ventricular wall (RUSTED et coll)

4 In extreme shortening of the chordae, direct attachment between the margin of the leaflet and the papillary muscle may exist The muscle may be more or less fixed to the ventricular wall (BAILEY 1955)

Calcifications may be present in one or both commissures at the site of the fused margins of the leaflets and may extend onto the free margins The basal parts of the leaflets are not as a rule, calcified (EDWARDS 1961)

In incompetence the following pathologic changes may be observed

1 Enlargement of the left atrium with distention of the annulus produces a postero-inferior displacement of the posterolateral leaflet This may lead to deficient contact between the leaflets on closure (LEVY & EDWARDS)

2 Congenital or acquired defects of the leaflets lead to incompetence (LEVY & EDWARDS) On the other hand shrinkage of the posterolateral leaflet is generally compensated by the larger more mobile anteromedial one (MC KUSICK 1958) Fusion in the region of the commissures usually leads to stenosis, although cases exist in which fusion tends to separate the leaflets (LEVY & EDWARDS)

3 Changes in the chordae may produce incompetence of the valve either by insufficient or excessive traction The former occurs on chordal rupture as well as in displacement of the chordae and papillary muscles When the postero lateral leaflet is displaced due to left atrial enlargement the chordae cannot exert traction in the longitudinal direction of the leaflet which leads to a de creased effect This also applies in generalized enlargement of the left ventricle when the papillary muscles are displaced laterally and the course of the chordae becomes oblique so that their traction force is reduced Excessive traction occurs in fusion and shortening of the chordae and prevents satisfactory apposition of the margins of the leaflets On enlargement of the left ventricle in the longitu dinal direction e g in aortic stenosis the distance between the margins of the leaflets and the papillary muscles increases This may be partly compensated but severe displacement leads to incompetence even if no pathologic changes are present in the chordae (LEVY & EDWARDS AMADOR et coll)

4 In addition to the aforementioned displacement of the chordae and papil lary muscles rupture of a papillary muscle after infarction can lead to in competence (LEVY & EDWARDS)

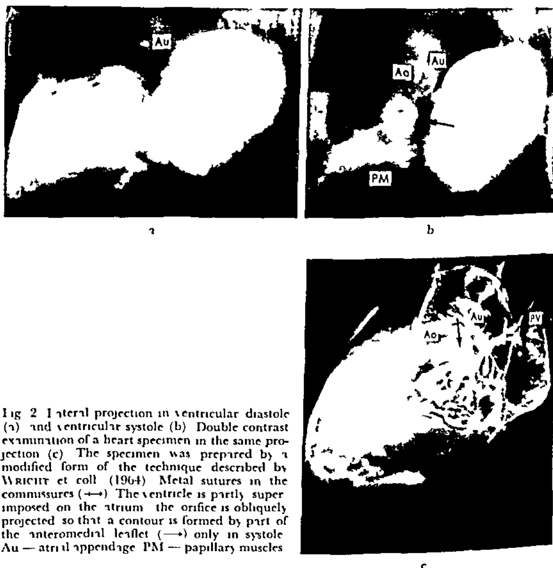


Fig. 2. Lateral projection in ventricular diastole (a) and ventricular systole (b). Double contrast examination of a heart specimen in the same projection (c). The specimen was prepared by a modified form of the technique described by WRIGHT et coll. (1964). Metal sutures in the commissures (→). The ventricle is partly superimposed on the atrium: the orifice is obliquely projected so that a contour is formed by part of the anteromedial leaflet (→) only in systole. Au — atrial appendage. PM — papillary muscles.

2. The leaflets may be thickened and the mobility impaired. The changes are most conspicuous at the line of closure. The anteromedial leaflet is more often involved than the posterolateral (RUSTED et coll. 1956, AMADOR et coll. 1963). More or less complete fusion between the margins of the leaflets in the region of the commissures is usually present, and one or both commissures may be affected. Fusion leads to the typical funnel shape (RUSTED et coll., AMADOR et coll.).

3. The chordae become thickened, with fusion both between them and between the chordae and the leaflet margin. This leads to elongation of the leaflet and shortening of the chordae (MAGAREY 1951, TWEEDY 1956). Since

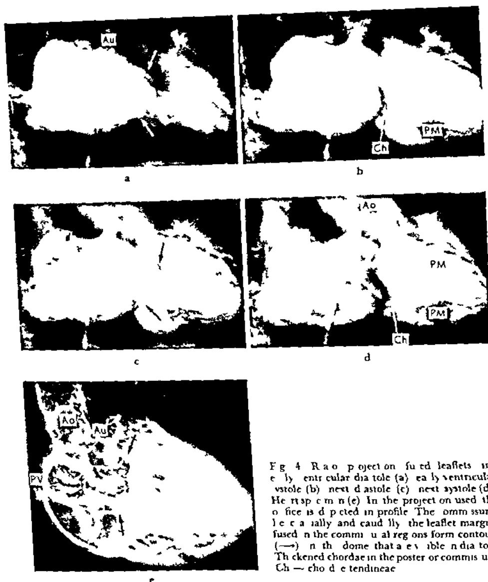


Fig 4 R a o projection fused leaflets in early ventricular diastole (a) early ventricular systole (b) next diastole (c) next systole (d) Heart specimen (e) In the projection used the orifice is depicted in profile The commissures lie cranially and caudally the leaflet margins fused in the commissural regions form contours (—→) in the dome that are visible in diastole Thickened chordae in the posterior commissure Ch — chordae tendineae

Right anterior oblique projection (r a o) If the rotation amounts to about 30 the mitral orifice will be depicted tangentially (Figs 1 and 4) The orifice will thus be seen in profile without superimposition of ventricle or atrium This implies a possibility of observing the annulus and of measuring variations in its diameter The movements of the valvular apparatus are also easy to define



Fig. 3. Lateral projection with contrast medium injected into the left ventricle. The fresh blood from the atrium forms a filling defect (→) indicating the great extent to which orifice is obliquely projected.

Comments. In both mitral stenosis and incompetence an interaction between the different components is often responsible for either of these conditions. Moreover, stenosis generally contains an element of incompetence, and vice versa. Pure stenosis may occur if the lesions are confined to fusion of the leaflet margins in the region of the commissures, whereas pure incompetence can be envisaged if the chordae are shortened only (BAGGENSTOSS 1953).

Normal angiocardiographic appearances in different projections

Lateral projection. A true lateral projection implies that the mitral orifice will be obliquely projected, with the left atrium and ventricle partly superimposed on each other (Figs. 1 and 2). This not only produces difficulties in delimiting the annulus but also hampers identification of the two leaflets, since they are to some extent axially projected. Thus, the closed leaflets do not form a contour but appear as a surface. When both ventricle and atrium are filled with medium they cannot be observed in ventricular systole. The extent to which the orifice may be axially projected can be inferred from Fig. 3. In ventricular diastole, blood from the atrium, unmixed with medium, does not form a break in the contour but produces a filling defect in the medium corresponding to the orifice. Posteromedial chordae as well as the posterior papillary muscle, can usually be identified, although these structures are also obliquely projected



a



b



c

Fig 6 Frontal projection a) Injection into left atrium the orifice is not demonstrated due to superimposition of the ventricle b) The orifice appears as a filling defect c) Specimen in the same projection

are superimposed on the atrium The orifice cannot therefore be evaluated on injection of contrast medium into the left atrium (Fig 6a) but only on its injection into the ventricle when the inflowing blood from the atrium unmixed with medium forms a round filling defect (Fig 6b) This projection offers no possibility of assessing leaflets chordae and papillary muscles

Left anterior oblique projection (l a o) The orifice is depicted axially in this projection (Figs 1 and 7) As in the frontal projection superimposition implies that it is visible only as a filling defect in diastole and the leaflets or other structures cannot be evaluated in this projection

Comment The ideal projection for evaluating the appearance and mobility of the leaflets would be the l a o position with the roentgen tube angled 70



Fig 5 R a o projection healthy leaflets in ventricular systole (a) and ventricular diastole (b) Basal parts of leaflets visible in systole (←) but no leaflets evident in diastole since they do not form an outline (*Extensive filling of the pulmonary veins due to the fact that in the course of injection the catheter changed position so that some of the medium was injected directly into the veins*)

since the direction of movement is at right angles to that of the beam The individual leaflets cannot, however, be evaluated This is because, as evident in Fig 1c, this projection involves the leaflets being largely projected frontally Healthy leaflets are visible only in ventricular systole, when they bulge up towards the atrium and form the roentgenologically detectable contour (Fig 5) A prerequisite for the leaflets being visible in diastole is their fusion into a funnel shape

When the valve is open, it is the peripheral margins of the fused leaflets that are visible in the angiocardiograms, whereas it is the basal parts of the closed leaflets that appear in systole This implies that different parts of the leaflets are visible during the various phases of the cardiac cycle, and this gives the impression of greater mobility than actually exists

In the r a o projection, the papillary muscles and chordae are seen in profile, which affords a possibility of evaluating them Evaluation of the chordae is, however, hampered by the fact that they are visible only when there is a small quantity of medium in the ventricle i e towards the end of systole when in this projection, the filled aorta is partly superimposed on the anterior chordae (Fig 4d)

Frontal projection A true frontal projection, like the lateral, implies that the orifice is projected obliquely (Figs 1 and 6) With an a p direction of the beam the oblique projection is much more marked and large parts of the ventricle

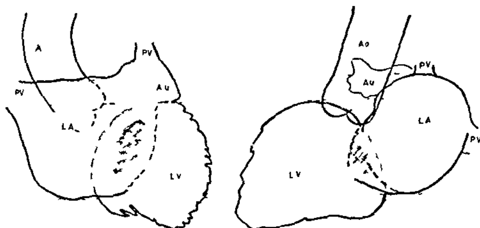


Fig 8 Sketch of figs 2a nd f a which represent s multaneously exposed films in frontal and late al projecti ns The collocat on ind cates the high degree of superimpos t on (hatched area) (Review of all the fil ns in the ser es suggested the probable position of the orifice (shadowed area)

to 90 cranially i e with the direction of the beam nearly in the longitudinal direction of the body but this is impracticable

Various projections have been used in the first angiocardiographic studies of the left side of the heart (ROBB & STEINBERG 1939 DOTTER & STEINBERG 1951) The former authors pointed out that the r a o position gives a sideview of the heart However since in the subsequent development interest was concentrated on determining the position and size of the heart chambers (STEINER 1954 MCAFFEE et coll 1956 ARVIDSSON 1958) or calculating the circulation time (ZINSSER & JOHNSSON 1953 SOLOFF et coll 1956) the frontal and lateral projections became the standard ones

Once selective angiocardiography had been introduced, sufficient filling was achieved to evaluate the mitral orifice ARVIDSSON stated that in 43 of 56 cases with stenosed leaflets these were visible in the lateral view He emphasized the characteristic ballooning of the leaflets due to the pressure gradient THURN et coll (1962) also used the lateral projection to evaluate the mitral leaflets He noted that the anterior leaflet is easy to identify as a continuation of the posterior aortic outline (cf Fig 2b) whereas the posterior one is harder to localize It is evident from Figs 2 and 8 that it is only an oblique projection of the anterior leaflet that is visible in systole and that the posterior leaflet never forms a contour In left atrial enlargement the caudal wall of the atrium is superimposed on the ventricle and the tangentially depicted part of the atrial wall produces a filling defect in the lower part of the orifice (Fig 8) To denote this as the posterior leaflet (ARVIDSSON 1961) is erroneous



Fig. 7. Lateral projection, injection into the left ventricle, first ventricular diastole (a), next diastole (b). Heart specimen (c). The orifice is depicted axially; the slit shaped opening between the leaflets (—) is evident in the specimen.

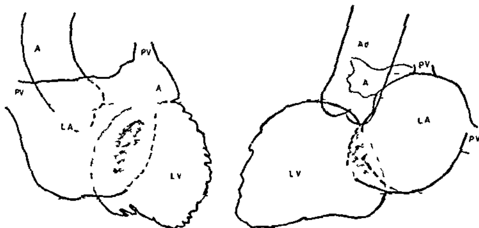


Fig 8 Sketch of figs 2a and 6a which represents simultaneously exposed films in frontal and lateral projections The collocation indicates the high degree of superimposition (hatched area) (Review of all the films in the series suggested the probable position of the orifice (shadowed area)

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The lateral projection gives an oblique view of the orifice and it is thus unsuitable for judging the appearance and mobility of the leaflets

BJORK et coll (1955) were the first to demonstrate the mitral leaflets at angiocardiography, and they used the r a o position in order to depict the orifice in profile Subsequently, this projection has generally been used for studying the mitral orifice (MOUQUIN et coll 1956, BJORK & LODIN 1959, KJELLBERG et coll 1961, ROSS et coll 1961, 1962, 1964, BRAUNWALD et coll 1962, STEINHART et coll 1962, 1963, SCHAEFER et coll 1963, FIGLEY 1964) KJELLBERG et coll, in their detailed analysis of the appearance of the mitral orifice in stenosis and incompetence, stated that the essential factor is presumably that the dome formation of the stenosed leaflets allows them to be depicted tangentially ROSS et coll, and FIGLEY, also emphasized that a prerequisite for demonstration of the leaflets is that they are fused into a funnel They stressed that the reason why healthy leaflets cannot be seen is not that they are so thin or move so rapidly that they cannot be demonstrated angiocardiographically but that in this projection the leaflets are largely depicted frontally and therefore do not produce any visible filling defect They reached this conclusion by studying the movements of the leaflets at cine angiocardiography

A comparison between specimens and angiocardiograms also disclosed that the leaflets are projected frontally (Fig 4) In addition, the position of the papillary muscles on the angiocardiograms permits conclusions about the projection of the leaflets The muscles are depicted on the films in profile at the top and bottom (Figs 4d and 9c), and since these muscles lie directly below the corresponding commissure, it is the leaflet margins that are fused at the commissures which are depicted tangentially The filling defects marked by arrows in Fig 4, a and c thus represent the fused margins of the leaflets or the commissural region of the leaflets, and the common view that they represent the anterior and posterior leaflets is incorrect

Angiocardiographic findings in pathologic conditions

In order to ascertain to which extent pathologic changes occurring in mitral stenosis and incompetence can be demonstrated, the angiocardiographic examinations that had been made to study the orifice were reviewed

Only films of good technical quality were included This was because the aim was not to illustrate the value of a certain method but to show the possibility of demonstrating these pathologic changes by angiocardiography

The contrast medium was injected as close as possible to the orifice, proximally (into the left atrium) in stenosis, and distally (into the left ventricle) in incompetence, according to the principles of BJORK & LODIN (1959) and

KJELLBERG et coll For injection into the left atrium a catheter was introduced trans septally according to a modified Ross technique (PAULIN & VARNAUSKAS 1962) Injection into the left ventricle was made through a catheter introduced via the aorta The distal end of that catheter was usually in the form of a loop (PAULIN 1962) Only films in which the r a o position was employed were included in this review

The review covered 55 angiocardiographic examinations made in 20 men (average age 48 4 years) and 29 women (average age 47 8 years) The sites of injection in the different pathologic conditions were as follows

	Stenosis	*Stenosis plus incompetence*	*Stenosis but no incompetence*
Left atrium	30 cases	1 case	—
Left ventricle		9 cases	3 cases
Left atrium plus ventricle		3 cases	3 cases

Cine film was used in 41 examinations (9 inch image intensifier 35 mm film camera with 48 frames/sec) and in the remaining 14 examinations full size films were the rule (Elema Schonander roll film changer 6 films/sec)

Mitral stenosis was present in all the cases i e a dome formation of the leaf lets was visible This was most distinct on injection of the contrast medium into the left atrium particularly in the first films in diastole after starting the injec tion (Figs 4a 9b and 11) The dome was also present on injection into the left ventricle when it appeared as a negative filling defect No bulging of the leaf lets towards the atrium was evident in systole in marked stenosis (12 cases) but the valvular plane was straight or slightly concave

Mitral incompetence was diagnosed in 12 cases since the medium regurgitated from the ventricle to the atrium (Fig 10) In the remaining case in which the medium was injected into the atrium incompetence was established by demon stration of a distinct reflux of contrast mixed blood to the pulmonary veins in ventricular systole Incompetence was probably also present in some other cases in which the medium was injected into the atrium Since the examina tions were made with a view to study the mitral orifice the film field was often too small to permit the pulmonary veins to be evaluated Moreover a detailed study of the variations in volume of the atrium in relation to ventricular systole is beyond the scope of this paper

A stenotic component of varying degree was apparent in every case of mitral incompetence Since no possibility existed of distinguishing angiocardiographic ally between the pathologic changes in stenosis and incompetence respectively these will be described collectively

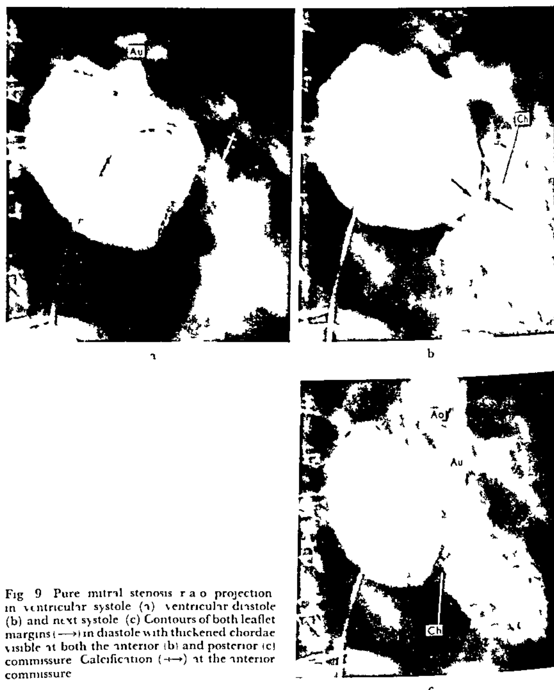


Fig 9 Pure mitral stenosis r a o projection in ventricular systole (a) ventricular diastole (b) and next systole (c) Contours of both leaflet margins (—→) in diastole with thickened chordae visible at both the anterior (b) and posterior (c) commissure Calcification (→←) at the anterior commissure

1 *Annulus fibrosus* Variations in diameter of the annulus were measurable in all but three cases (8%) on injection into the left atrium In these three cases, the exposure rate was 6 films/sec and a higher frequency is needed if the annulus is to be localized with certainty It is possible, in cineangiocardio

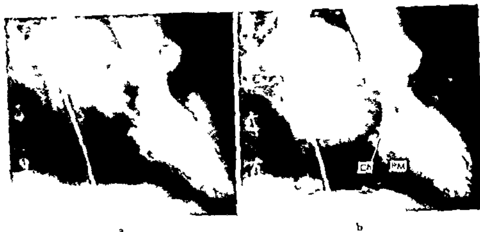


Fig 10 Mitral incompetence and stenosis r a o projection in first ventricular systole (a) and at end of next systole (b) There is a marked regurgitation of contrast medium The chordae in the posterior group are outlined in (b)

grams before filling of the ventricle to follow movements of the atrial wall and valvular apparatus in frame after frame The site where these movements meet represents the annulus (Fig 11) The annulus is harder to identify on injection into the ventricle This is because there is either no filling of the atrium — in which event its wall is not evident — or the atrium is filled concurrently with the aorta which is projected over the anterior cranial part of the annulus The annulus is thus visible only in systole at the site where the concavely bulging valvular plane passes into the atrial wall In two cases of injection into the ventricle both diameters could be measured whereas in four only the systolic diameter was measurable The enlargement factor could be calculated from the outer diameter of the catheter and the measurement made on the films Since extremely small measures are involved the margin of uncertainty is wide

The decrease during systole of the surface delimited by the annulus could be calculated in 36 cases The decrease ranged from 0 to 48% (mean 22 6%) If the 12 cases with no or inappreciable variation in diameter of the annulus are compared with the 12 that had the largest variations the mean diameter in the former group is found to be 43 5 mm and that in the latter group 38 5 mm The difference between these values is significant This implies that decreased mobility of the annulus is due rather to it being distended than to it being contracted and sclerotic

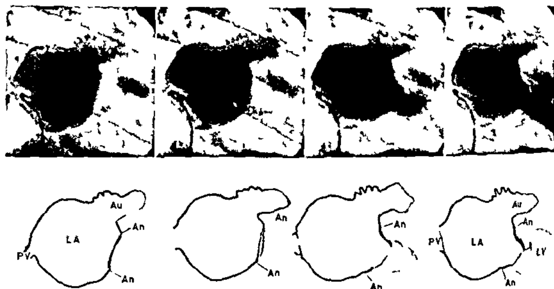


Fig 11 Four cine angiographic frames (upper views) show the movements of the atrial wall and the valvular apparatus from systole to diastole The sketches are presented to clarify the site of the annulus fibrosus (An)

Fig 12 is a graphic representation of the systolic diastolic variation in diameter of the annulus The cases with small variations lie in the upper half of the diagram, i e the diameter is large It is also apparent that the values are higher in men than in women, the mean diameter is 42 5 mm in men and 38 5 mm in women The difference is not significant, however The corresponding values for the circumference are 13 3 cm in men, and 12 1 cm in women

2 *Leaflets* The r a o position has previously been shown to imply that both leaflets are largely projected frontally (cf p 280 and Fig 4) Irregularities and thickening of the actual leaflets cannot therefore be observed, nor can the mobility of the individual leaflets be evaluated Moreover, the movement visible in the angiocardiograms is an expression of the mobility of the whole valvular apparatus, and not merely of the rigidity of the leaflets If any chordal changes are present and slow down the leaflets, this is also reflected in the movement recorded angiocardiographically Furthermore, as pointed out earlier, this movement is a false representation of the true one, since different parts of the valvular apparatus are visible in different phases of the cardiac cycle

The fused margins of the leaflets in the region of the commissures comprise the filling defects in the orifice seen in the angiocardiograms In every case in which both the atrium and ventricle were filled, the thickness of these regions could be

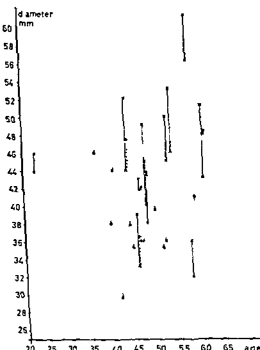


Fig 12 Diagrammatic representation of the systolic diastolic variations in diameter of the annulus Cases with no or small variations lie chiefly in the upper half of the diagram i e they have a larger diameter ×——× men ○— — —○ women

assessed Irregularities in the margin are as a rule due to fusion with thickened chordae, and could be seen concurrently (Figs 4d and 9c)

The orifice (the distal opening in the funnel composed of the fused leaflets) could be measured only with respect to one diameter since only one projection was used Because of the position of the leaflets this consisted of the longer diameter of the orifice which is generally stenosed in the form of a slit A prerequisite for measuring the orifice is that a distinctly delimited jet of contrast medium is present The distance between the filling defects does not in fact necessarily represent the orifice since some of the defects may consist of the thickened free margin of the leaflet These defects can in certain cases be seen to extend in the shape of an arch along the whole leaflet margin (Fig 9b)

In the presence of stenosis the distance measured corresponds to the longest diameter of the orifice when it is fully open In incompetence however the regurgitated jet of medium comprises the diameter of the opening formed by the incompletely closed leaflet The longest diameter of the orifice could be measured in 11 cases in which the medium was injected into the atrium The values ranged from 10 3 to 17 7 mm In three cases of injection into the ventricle when

regurgitation permitted measurement, the diameter was found to be from 10.4 to 12.6 mm. The practical value of such measurements is nevertheless dubious since only one diameter can be determined.

3. *Chordae tendineae.* As pointed out earlier, the chordae can be evaluated only when there is a small quantity of medium in the ventricle, and it is then difficult to identify the anterior group since the aorta is partly superimposed (cf. p. 280). This difficulty increases if the medium is injected into the ventricle. The anterior group was not visible in three cases of atrial injection (8%) and in 10 cases of ventricular injection (56%). The posterior group could not be seen in two cases of ventricular injection (11%) but could be assessed in every case of atrial injection. The anterior chordae were considered to exhibit pathologic changes in 21 cases (50%) and the posterior chordae in 32 (60%). No possibility existed of measuring the length of the chordae, since in systole, when they may be observed, the basal parts of the leaflets, but not the margins, to which the chordae are largely attached, are visible.

4. *Papillary muscles.* Fusion with the ventricular wall cannot be demonstrated by angiocardiography in view of the varying appearance of the papillary muscles, single headed or multi headed. No case of direct fusion between papillary muscle and leaflet margin could be observed. The papillary muscles, like the chordae, appear most distinctly in systole whereas they may be difficult to indentify in the distended ventricle.

Calcifications were observed in 16 cases, in six of which they were present in both the anterior and the posterior commissures. In five cases, calcifications were evident only in the anterior commissure and in four only in the posterior. One case had calcifications both in the commissures and in the annulus, whereas in another one only an annular calcification was present.

Discussion

ARVIDSSON stressed the diagnostic value of the ballooning of the stenosed leaflets due to the pressure gradient. This was further emphasized by KJELLBERG et coll., who demonstrated that in all cases of stenosis the fused leaflets form a typical dome in the angiocardiograms. The leaflets exhibit not only retardation of movement but also a decreased amplitude, so that the systolic bulging towards the atrium is less extensive in stenosis. BJORK & LODIN (1960) demonstrated that the typical dome formation of the leaflets can be observed as a filling defect on injection into the left ventricle. However, on injection into the ventricle, only the movement can be evaluated and not the pathological appearance of the valvular apparatus unless severe incompetence is present.

It was not until Ross et coll made their cine angiocardiographic studies that it was established that the contours of the dome are formed not by the anterior and posterior leaflets but by their margins which are fused at the commissures The fact that it is different parts of the leaflets that are visible in the angiocardiograms during systole and diastole and that the films thus give the impression of a larger movement than actually takes place, had not been pointed out earlier

Since no previous angiocardiographic studies had been made of the changes in the annulus fibrosus no comparative material is available DAVIS & KINMONTH found that in the dog the surface of the mitral plane normally decreases by 24 to 54% in systole RUSTED et coll and CHIECHI et coll measured the circumference of the annulus in anatomic specimens, and gave the mean value as 10 cm in men and 8 5 to 9 cm in women The discrepancy between these values and mine are probably to be ascribed to shrinkage of the anatomic specimens

Judging by the values measured from angiocardiograms it seems to be principally the distended annulus which has decreased mobility A decrease in mobility of the annulus in stenosis reported by HARKEN et coll was not demonstrable in the present study It is on the other hand conceivable that the distension of the annulus combined with an impaired ability to contract in systole contributes to mitral incompetence The number of cases of definite incompetence in the present series, in which the variations in size of the annulus were measurable is, however too small to permit any conclusions

It has been stated by thoracic surgeons that unsatisfactory results of commissurotomy may be due to complete fusion of the chordae tendineae (HARKEN et coll BJORK 1961) Consequently angiocardiographic evaluation of the chordae is valuable KJELLBERG et coll reported that changes only in the posterior group could be observed In the present series the anterior group of chordae could also be assessed in several cases this may have been due to the fact that the chordae are visible only during a brief part of the cardiac cycle and that the rapid movement is easier to observe at cine angiocardiography

Regurgitation of contrast medium through the orifice is a typical feature of mitral incompetence The catheter should be advanced into the ventricle in a retrograde direction from the aorta to demonstrate it If it is advanced through the orifice (STEINHART et coll) false regurgitation may occur This may also arise if the jet of medium is directed towards the orifice and use was made of a loop catheter to avoid this (PAULIN) No great risk of arrhythmia elicited by injection into the ventricle leading to regurgitation (BJORK et coll 1960) appears to exist It is easier at cine angiocardiography to detect the phase in the cardiac cycle during which regurgitation takes place and even

small quantities of regurgitated medium can be demonstrated Organic mitral regurgitation occurs in systole, and a systolic reflux to the pulmonary veins is characteristic Reflux in association with atrial contraction is a normal event (Ross et coll 1961)

Apart from the demonstration of regurgitation of contrast medium, the present review disclosed no angiocardiographic changes in the mitral orifice that may be considered typical of mitral incompetence

Conclusions

For the angiocardiographic evaluation of the various components of the mitral orifice (1) the annulus fibrosus, (2) leaflets and commissures, (3) chordae tendineae, and (4) papillary muscles, an attempt should be made to depict the orifice in profile The best possibility of achieving this is to perform the examination in the right anterior oblique position In other projections, the orifice is depicted obliquely, with the left ventricle partly superimposed on the left atrium

The leaflets are largely projected frontally in the r a o position This implies that healthy leaflets are represented only in ventricular systole when basal parts of the closed leaflets form a contour against the atrium A prerequisite for demonstration of the open leaflets is that they are fused into a dome The outlines of this dome are formed by the fused leaflet margins Thickening and irregularities in this region can be seen, whereas the anteromedial and posterolateral leaflets cannot be evaluated Different parts of the leaflets are visible in systole and in diastole The movement evident in the films is consequently a false representation of the true movement, which is smaller

Impaired mobility of the annulus occurs chiefly when it is distended

The possibility of seeing the chordae tendineae is greater on injection of medium into the atrium than into the ventricle In the r a o position, the aorta is partly superimposed on the anterior group of chordae, which hampers their evaluation The posterior group could be observed in almost every case of the present series

In view of the anatomical variations in appearance of the papillary muscles, any existing abnormalities cannot be assessed at angiocardiography

Current angiocardiographic techniques offer good opportunities of preoperative evaluation of pathologic changes in the mitral orifice Prerequisites are that a suitable projection is used, and that the roentgenologic observations are correctly correlated to corresponding anatomic structures

SUMMARY

The appearances of the mitral orifice in different projections during angiography are described The movement of the valvular apparatus the outlines of the fused structures mobility of the annulus fibrosus and pathologic changes in the chordae tendineae may be observed in mitral stenosis Mitral incompetence may be diagnosed by the demonstration of regurgitation through the orifice in systole and by systolic reflux to the pulmonary veins

ZUSAMMENFASSUNG

Das Bild der Mitraloffnung wie es bei verschiedenen Projektionen wahrend der Angiographie erscheint wird beschrieben Die Bewegung des Klappensystems das Bild der verklebten Klappen die Beweglichkeit des Mitralringes und pathologischen Veranderungen der Chordae tendineae bei Mitralstenose konnen studiert werden Die Mitralinsuffizienz kann durch die Regurgitation durch die Mitraloffnung wahrend der Systole und durch systolischen Ruckfluss gegen die Lungenvene erkannt werden

RÉSUMÉ

L auteur décrit les aspects de l orifice mitral dans différentes projections au cours de l angiographie Dans la sténose mitrale on peut observer le mouvement de l appareil valvulaire les contours des structures fusionnées la mobilité de l annulus fibrosus et les modifications pathologiques des cordages tendineux L insuffisance mitrale peut être diagnostique par la mise en évidence de la régurgitation par l orifice pendant la systole et par le reflux systol que vers les veines pulmonaires

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Table 1

Age and sex distribution in groups I II and III

	Group I Pyelonephritis	Group II Nephrosclerosis	Group III Other conditions
Number of cases	11	12	19
Average age	42 7 ± 13 14	47 0 ± 14 12	38 1 ± 10 00
	Age difference not significant (P > 0 05)		
Ratio females males	7 4	7 5	10 9
	Sex distribution difference not significant (P > 0 05)		

The remaining 42 cases have been divided into the following three groups according to the final clinical diagnosis verified in several instances by biopsy or autopsy

Group I Pyelonephritis and chronic interstitial nephritis including one case of severe unilateral hydronephrosis

Group II Nephrosclerosis

Group III Other conditions mostly essential hypertension glomerulonephritis or tuberculosis

Healthy individuals have not been included in this series and with a few exceptions renal disorder was present in all The history did not in any of the cases reveal any acute attack suggesting temporary or permanent arterial or uretric occlusion to have occurred within several months prior to the examination There was no significant difference in average age or sex distribution between groups I II and III (see Table 1)

Methods

1 *Nephroangiography* All examinations were carried out by percutaneous transfemoral catheterisation of the abdominal aorta In 29 cases the contrast medium was injected while the patient was straining (LUDIN 1962) Unlike the aortic calibre the width of the renal arteries is not measurably influenced by the Valsalva manoeuvre (LUDIN 1966)

2 *Determination of the size of the kidneys* The relatively high density of the resulting nephrograms permitted an exact determination of the size of the kidneys When angiography was carried out with the patient straining the kidney areas were determined in the last film i e 12 sec after straining had ceased in order to prevent geometric errors due to displacement and/or

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CORRELATION OF RENAL SIZE, RENAL ARTERY CALIBRE AND EFFECTIVE RENAL PLASMA FLOW IN MAN

by

H LUDIN, M ELKE, H FEHR and H THOELEN

Stenosis of the renal arteries has been a subject of intense physiologic and clinical investigation Changes in the renal arterial calibre may however occur without stenosis Dilatation of these arteries may be observed for instance after contralateral nephrectomy whereas narrowing is often evident in severe renal parenchymal diseases

An attempt has been made to find out whether a correlation exists between the size of the kidneys, renal arterial calibre and renal blood flow, as well as whether the observation that in pyelonephritis the renal arteries are especially narrow in relation to renal size is correct, at least as long as the kidneys have not yet shrunk markedly

Material Nephroangiography and determination of the effective renal plasma flow were carried out in 47 cases between March 1959 and March 1963 Five were excluded, two because the angiographies were inadequate, one because the renal artery on one side was found to be occluded, and two because only one kidney had been examined by selective angiography

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Table 2

Average values of kidney area cross sectional area of renal arteries effective renal plasma flow and significance of the difference between average values in the material

	Kidney area (right + left) (cm)	Cross-sectional area of renal arteries (right + left) (mm)	C_{PAH} (effective renal plasma flow (right + left) (ml per minute)
Group I Pyelonephritis	115 1 ± 40 9	4[illegible] 0 ± 16 09	263 ± 178 3
Group II Nephrosclerosis	119 0 ± 23 22	60 7 ± [illegible]9 48	30[illegible] ± 146 5
Group III Other conditions	12[illegible] 7 ± 19 42	68 7 ± 24 9[illegible]	469 ± 190 3
Difference of average values	I/II P > 0 05	P < 0 0[illegible]	P > 0 05
	I/III P > 0 05	P < 0 001	P < 0 001
(Probability of error)	II/III P > 0 05	P > 0 05	P < 0 01

Table 3

Average ratios between the sum of the areas of both kidneys and the sum of the renal arterial cross sectional areas The difference in the average ratios between groups I and III is significant (probability of error P ≈ 0 05)

	Number of cases[1]	Average ratio $\bar{q} = \frac{A_k - 40}{A}$ cm /mm (Ludin et coll 1965)
Group I shrunken kidneys	10	1 64 ± 0 546
Group I non-shrunken kidneys	6	1 75 ± 0 475
Group II	12	1 332 ± 0 339
Group III	16	1 3[illegible]3 ± 0 4[illegible]0

All cases with moderate or severe hydronephrosis have been excluded
Four cases with markedly shrunken kidneys (A_k < 8[illegible] cm) have been excluded

flow (Fig 2) is highly significant (P ≪ 0 001) No difference exists between groups I II and III The regression line intersects the abscissa close to the O point

Discussion

The present material indicates (1) a significant correlation between the renal arterial calibre and effective renal plasma flow and (2) in pyelonephritis that the renal arteries are especially narrow in relation to kidney size at least as long as the kidneys have not yet markedly shrunk

rotation of the kidneys induced by the Valsalva manoeuvre (LUDIN 1961). The figures given represent the sum of these areas of both sides.

3. *Determination of cross sectional area of the renal arteries.* The upper and lower outlines of the renal arteries were marked at distances of 1, 1.5 and 2 cm from the aortic origins of the arteries. Allowance in measuring the diameter was thus made for the funnel like constriction of the renal arteries; this constriction is most marked in narrow renal arteries without stenosis and corresponds to the jet contraction described by ROUX (1895), PRANDTL (1944), and others. In some instances a further slight tapering of the renal arteries towards the periphery was noted. The width of the arterial lumen was determined under optical magnification with a precision of about ± 0.1 mm. As in the determination of kidney areas no correction was made for geometric magnification. The renal arterial cross section was assumed to be round; the cross sectional area was computed from the arterial width and the figures given represent the sum of the cross sectional areas of the renal arteries of both sides, using the average of the three measurements obtained by the method described.

4. *Determination of effective renal plasma flow.* The PAH clearance was in only one case determined for each side separately. The figures given represent average values derived from several measuring periods without reduction to standard body surface.

Results

The average kidney area (Table 2) does not differ significantly from the normal, and there is no significant difference between groups I, II and III.

Average cross sectional area of renal arteries (Table 2). The arteries are significantly narrower in cases of pyelonephritis than in other cases. There is no significant difference between groups II and III, probably due to the small number of observations.

Average effective renal plasma flow (Table 2) is markedly reduced in groups I and II as compared with group III. There is no significant difference between groups I and II.

Correlation between kidney size and width of renal arteries. In agreement with the difference of average values (Table 2), there is a significant difference in the average ratio of kidneys area to renal artery cross sectional area between groups I, II and III (Fig. 1 and Table 3). This means that in pyelonephritis the renal arteries are especially narrow in relation to renal size, signs which are very different from those in nephrosclerosis, particularly when the kidneys are not yet markedly shrunken. There is no correlation of the ratio q as defined above with systolic or diastolic blood pressure ($p > 0.05$).

The correlation between renal arterial calibre and effective renal plasma

Table 2

Average values of kidney area, cross sectional area of renal arteries, effective renal plasma flow and significance of the difference between average values in the material

	Kidney area (right + left) (cm^2)	Cross sectional area of renal arteries (right + left) (mm^2)	C_{PAH} (effective renal plasma flow (right + left) (ml per minute)
Group I Pyelonephritis	115.1 ± 40.9	42.0 ± 16.09	263 ± 178.3
Group II Nephrosclerosis	119.0 ± 23.2[illegible]	60.7 ± 29.48	306 ± 146.5
Group III Other conditions	125.7 ± 19.4[illegible]	68.7 ± 24.96	469 ± 190.3
Difference of average values (Probability of error)	I/II $P > 0.05$	$P < 0.05$	P [illegible] 0.05
	I/III $P > 0.05$	$P < 0.001$	$P < 0.001$
	II/III $P > 0.05$	$P > 0.05$	$P < 0.01$

Table 3

Average ratios between the sum of the areas of both kidneys and the sum of the renal arterial cross sectional areas. The difference in the average ratios between groups I and III is significant (probability of error $P \approx 0.05$)

	Number of cases	Average ratio $\bar{q} = \frac{A_k - 40}{A}$ cm^2/mm^2 (Lupry et coll 1965)
Group I shrunken kidneys	10	1.64 ± 0.546
Group I non shrunken kidneys	6	1.75 ± 0.475
Group II	12	1.33[illegible] ± 0.339
Group III	16	1.323 ± 0.420

All cases with moderate or severe hydronephrosis have been excluded
Four cases with markedly shrunken kidneys ($A_k < 85$ cm^2) have been excluded

flow (Fig 2) is highly significant ($P < 0.001$). No difference exists between groups I, II and III. The regression line intersects the abscissa close to the O point.

Discussion

The present material indicates (1) a significant correlation between the renal arterial calibre and effective renal plasma flow and (2) in pyelonephritis that the renal arteries are especially narrow in relation to kidney size, at least as long as the kidneys have not yet markedly shrunk.

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The correlation between renal arterial calibre and effective renal plasma

From an equation derived by WOMERSLEY (1955) LUDIN (1964) has calculated the maximum systolic shearing force F, acting from the moving blood column on the wall of very small vessels of the order of arterioles $F \approx M \cdot A$, M being the modulus of the spatial pressure gradient in the direction of the vascular axis and A the vascular cross sectional area. The stress exerted on the vascular wall by this viscous drag is considered the mechanical cause of arteriolar lesions occurring in long standing pulmonary or systemic hypertension or hypercirculation, the spatial pressure gradient being especially high at the level of the arterioles. The unevenly distributed lesions in both pulmonary emphysema and pyelonephritis would then cause part of the arteriolar bed to vanish whilst the remaining arterioles remain intact and take over the entire circulation. Their compensatory dilatation has not been verified experimentally but would according to the equation above explain the need for a mechanism protecting these wide arterioles from mechanical damage. By constriction of the pulmonary or renal artery branches the spatial pressure gradient would be increased in the pre-arteriolar pulmonary or renal arterial branches and thus decreased in the arterioles. The zone of the greatest viscous drag and stress on the arterial wall would therefore be shifted from the arterioles towards the small sized arteries.

Renal arteriolosclerosis is a consequence of pre-existing systemic hypertension (ALLEN 1962). As soon as nephrosclerosis is established, a high systemic blood pressure is required to maintain kidney function. A diminution of the arteriolar spatial pressure gradient possibly produced by constriction of the renal arterial branches would thus be harmful in nephrosclerosis. In pyelonephritis, however, it might serve to prevent secondary arteriolosclerosis and systemic hypertension.

SUMMARY

A significant correlation was found between renal artery calibre and effective renal plasma flow in a material of 42 patients. In pyelonephritis the renal arteries are especially narrow in relation to renal size, at least as long as the kidneys have not markedly shrunk. A tentative explanation based on vascular mechanics is given for the constriction of the renal arteries and their intrarenal branches that was observed in cases of pyelonephritis.

ZUSAMMENFASSUNG

Eine signifikante Korrelation zwischen dem Nierenarterienkaliber und der effektiven renalen Plasmadurchströmung wurde an einem Material von 42 Patienten gefunden. Bei Pyelonephritis sind die Nierenarterien besonders eng im Verhältnis zur Nierengrösse, wenigstens solange die Nieren noch nicht stärker geschrumpft sind. Eine auf der Gefässmechanik beruhende pathophysiologische Erklärung für diese bei Pyelonephritis beobachtete Engstellung der Nierenarterien und deren intrarenalen Verzweigungen wird vorgelegt.

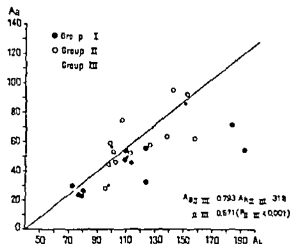


Fig. 1. Correlation between kidney area (Ak) and renal artery cross sectional area (Aa) in groups I, II and III. The regression line was computed from values of groups II and III only.

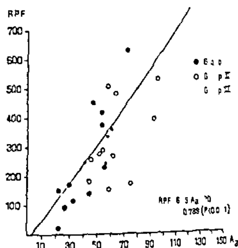


Fig. 2. Correlation between renal artery cross sectional area (Aa) and effective renal plasma flow (RPF) in groups I–III.

ad (1) The relatively great variance about the regression line in Fig. 2 is probably due to the following two reasons. First, there is a considerable fluctuation in the effective renal plasma flow values obtained successively in one patient. In addition, the time interval between aortography and determination of the renal clearance values varied in almost all cases between several days and two weeks. Secondly, the PAH extraction ratio and the haematocrit values (REUBI 1960) were not determined. The renal blood flow cannot therefore be estimated precisely from effective renal plasma flow.

When no localised renal artery stenosis is present, the rate of renal blood flow depends to a much higher degree on renal arteriolar than on renal arterial calibre (KRAMER 1959, THURAU & WOBER 1962). Thus, the correlation between artery calibre and blood flow implies an adjustment of arterial width to perfusion rate.

The above findings correspond to the results of animal experiments by IDBOHRN (1956) and WIDEN (1958).

ad (2) The especially marked constriction of the renal arteries and their intrarenal branches observed in cases of pyelonephritis is difficult to explain since groups I and II do not differ significantly in average effective renal plasma flow (Table 2). The authors will try to give a tentative explanation of this observation based upon a certain similarity between obstructive pulmonary emphysema and pyelonephritis, both diseases being inflammatory and non vascular in origin and focal, i. e. uneven, in distribution.

Book reviews

RONTGENBEFUNDE AM KINDLICHEN BECKEN BEI ANGEBORENEN SKELETTAFFEKTIONEN UND CHROMOSOMALEN ABERRATIONEN Von H J Kaufmann 86 Seiten 82 Abbildungen in 104 Einzeldarstellungen und 7 Tabellen Georg Thieme Verlag Stuttgart 1964 Preis DM 44

Erganzungsband No 93 in Fortschritte auf dem Gebiete der Rontgenstrahlen series is divided into four sections the first of which gives a comprehensive account of the embryology and radiography of the normal pelvis The second section deals with congenital malformations of the pelvis the third comprising almost half of the volume describes the appearances and evolution of the bony pelvis as part of the systemic disorders of the skeleton while the last part is devoted to chromosomal aberrations as reflected in abnormalities of the pelvis The author draws exhaustively upon his vast experience with special reference to 7 000 roentgenograms of the infantile and adolescent bony pelvis he quotes many illustrative cases from other sources as well and he has apparently assembled all the worthwhile information a a lable in the literature although any reference to Andrén s work on pelvic instability in congenital dislocation of the hip is notable by its absence The book bears the stamp of authority that comes only from first hand experience The text is clear and concise and the topography is almost free of misprints the whole is well illustrated although the reproductions do not always maintain the standard that has become associated with the name of Georg Thieme Verlag The excellent drawings make it easy however for the reader to grasp the diagnost c points of various pelvic disorders

The book contains a larg and well-chosen bibliography adequately covering the literature and useful to anybody interested in the radiology of abnormalities of the bony pelvis in infancy and childhood

Ulf Rudhe

DIE MEHRDIMENSIONALE VERWISCHUNG IM SCHICHTBILD DER LUNGE Von Claus Dieter Bloedner G Thieme Verlag Stuttgart 1964 Preis DM 18

The author after a brief historical introduction presents some experimental studies performed with phantoms consisting of groups of lead balls small aluminium plates and wires Comparisons are made between the tomographic results obtained with linear tomography and certain other types of tomographic motion The results may be somewhat misleading since linear tomography was performed with the direction of motion parallel to the sides of the square formed by the lead balls this caused the projections of the latter to be superimposed during blurring so that considerable striping was produced In such a comparison the interference between various objects should be avoided by a more careful planning of the experiments

The concept mehrdimensionale Verwischung (multidimensional blurring) in general ref rs to volume but it is here used in connection with something that mainly must be limited to a plane A m sunderstanding regarding the fundamental principles involved in blurring as obtained by l near and circular (ellipsoid or other) types of tomographs may exist The opin on is expressed that the blurring of object detail in th case of linear tomography is represented by a line and in circular tomography for instance by a surface This is wrong

RÉSUMÉ

Sur une série de 42 malades on a trouvé une corrélation significative entre le calibre de l artère rénale et le débit plasmatique rénal effectif Les artères rénales sont particulièrement grêles par rapport aux dimensions rénales dans la pyélonéphrite au moins aussi longtemps que les reins n ont pas notablement diminué de volume Les auteurs expliquent par un mécanisme vasculaire cette constriction des artères rénales et de leurs branches intrarénales observée dans des cas de pyélonéphrite

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ERRORS IN THE DIAGNOSIS OF ACHONDROPLASIA

by

FREDERIC N SILVERMAN and SAM BRUNNER

Among the various types of dwarfism achondroplasia is probably the best known Historically it is recorded in Egyptian art and representations in other forms of art have been known throughout the ages In the course of history many types of dwarfism have been confused having in common only the diminished stature Cretins pituitary dwarfs infants with rickets and osteogenesis imperfecta have been coupled in reports with classical achondroplastic dwarfs (RISCHBIETH 1912) In 1905 DURANTE drew attention to the fact that many different affections were classified under achondroplasia merely because of shortness of the extremities The first report (McINTOSH 1933) of chondroectodermal dysplasia (Ellis van Creveld syndrome) described the typical long trunk and short extremities of chondrodystrophy an obvious allusion to achondroplasia More recently the condition now recognized as metaphyseal dysostosis has been confused with achondroplasia (STEPHENS 1943) and McKUSICK (1964) has called attention to the inaccuracy of the reported frequency of achondroplastic dwarfs among the Amish of Pennsylvania and Ohio Some proved to be instances of the Turner syndrome pituitary dwarfism and mongolism but most of the severe dwarfism was

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since object detail not situated in the tomographic plane will spread out and therefore be blurred according to a pattern determined by the tomographic path. The blurring will thus appear as a straight line in linear tomography and as a curved line in tomography by means of other systems. It will never be a question of surfaces. True surface tomography can be approximately achieved only by using systems with a screw line or a scanning like type of movement. The reader therefore might get somewhat confused by the views expressed by the author.

Comparisons between linear and ellipsoid tomographic examinations in several clinically interesting cases are well illustrated and sometimes seem to point in favour of the simpler linear system for tomography. The author had noticed reduced definition with the ellipsoid system which he discusses and tries to explain. However, the results of experimental tests referred to in the introduction would seem to represent a more satisfactory image sharpness. It therefore seems reasonable to suppose that insufficient adjustment of the tomographic systems may have seriously interfered with the results. Most radiologists with practical experience from more complicated systems, e.g. with hypocycloid motion, have found that very good definition can be obtained.

A factor which may largely influence a comparison between different types of tomographic equipment is that the comparison often has to be made between planes that do not correspond. It should however be kept in mind that it is always difficult to achieve corresponding planes in repeated lung examinations. The discrepancy may also depend on inexactness in the apparatus when going over from one type of motion to another.

The wide clinical approach, with detailed information and operation specimens together with the roentgenograms, constitutes a valuable feature. The material is uniform and well selected.

O. e. Mattsson

X-RAY EXAMINATION OF THE STOMACH. A DESCRIPTION OF THE ROENTGENOLOGIC ANATOMY, PHYSIOLOGY AND PATHOLOGY OF THE ESOPHAGUS, STOMACH AND DUODENUM. By Fredric E. Templeton. Revised edition. 598 pages and 323 figures. The University of Chicago Press, Chicago 1964. Price 15 dollars.

An exhaustive study of this subject might reasonably be expected in this revised edition of a book running to 600 pages and containing 323 illustrations. However, the barium examinations are based on conventional radiology and no comparisons with gastroscopy, parietography or angiography have been attempted. The reader may therefore in many ways find the work a somewhat old fashioned but trustworthy compilation by an experienced examiner. The illustrations are generally good, if not of the highest quality. The personal approach in the text may give the book a certain charm but a firmer style might have added to the value of the book. The author deals thoroughly with the complicated structure of the lower esophageal segment but offers no solution to the problem of how to make the most of radiologic or anatomical findings. Radiology of the stomach, which constitutes the main part of the book, is well covered; the cases presented are interesting and should provide good examples in general teaching. The chapter on the post operative stomach is not so impressive and one feels that diagrams would have been valuable. The final chapters on the esophagus and foreign bodies are not of so great interest.

The book can be recommended particularly to students, and the more advanced radiologist may find its perusal to be of certain value.

J. Frimann Dahl



Fig 2 Classic achondroplasia a) Hydrocephalus is evident from the ventricular air short base and overhanging brow b) Half axial view supine Minute foramen *magnum*

spondylo epiphyseal dysplasia (FORD et coll 1961 MAROTEAUX & LAMY 1959) and others The feature which has permitted this differentiation has been a constantly recurring constellation of signs and symptoms in a pattern differing from the signs and symptoms which recur constantly in classical achondroplasia

Objections raised to the separation of spondylo epiphyseal dysplasia from achondroplasia have been related in part to the argument that achondroplastic dwarfs with normal craniums and with spine involvement have been reported in the literature A *normal* cranium in conjunction with serious vertebral deformity is of importance in the differentiation of the two conditions RISCHBIETH (1912) divided the case of *achondroplasia* into a classical type and into incomplete forms in which a certain number of the typical features are modified or absent *This latter* group included individuals with heads which were not very large or of the typical shape The detailed monograph of MORCH (1941) is also cited as *evidence that* achondroplasia can be present without involvement of the cranium and with scoliosis MORCH preferred the term chondrodystrophy *To* help define the condition he described confusing conditions in some detail especially what he called Silverskiold Morquio s disease which recent *writers* (LAMY & MAROTEAUX) classify among the epiphyseal dysplasias He emphasized the exaggerated changes in the epiphyses and the vertebral *column*, as well as the unaffected cranium The patients whom he reported as chondrodystrophic dwarfs presumably had what most authors today call achondroplasia

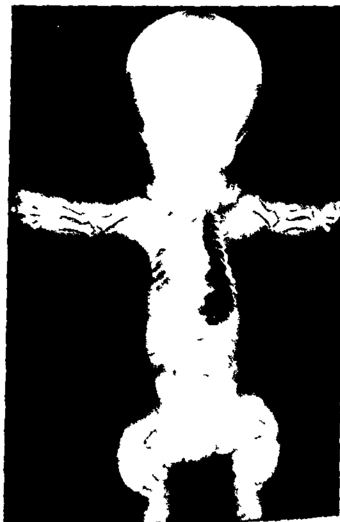


Fig. 1. Classical achondroplasia. Radiographic features are illustrated in the large cranial vault, the short thick bones of the extremities, the short ribs, the relatively long trunk, and the typical pelvic changes.

recognized as chondroectodermal dysplasia, and a form of metaphyseal dysostosis called cartilage hair dysplasia.

The term achondroplasia was introduced by PARROT (1878) to characterize the inadequate longitudinal proliferation of cartilage and the irregular formation from it of endochondral bone. KAUFMANN (1929) preferred chondrodystrophy (actually chondrodystrophia foetalis) because he felt that PARROT's term gave the false impression that no cartilage at all was formed. Many subsequent writers have used achondroplasia and chondrodystrophy interchangeably.

With the accumulation of experience, it has become possible to identify certain conditions as separate clinical entities, and to reduce the confusion in diagnosis. Thus, in recent years, we have learned to recognize additional entities such as diastrophic dwarfism (LAMY & MAROTEAUX 1960, TAYBI 1963)



Fig 5 Spondylo epiphyseal dysplasia Irregularity of epiphyseal ossification centres (Courtesy of Amer J Roentgenol)

genograms were provided We hoped to take advantage of the extensive files of roentgen films in Danish hospitals to review the radiographic features in the cases selected for study

Differential diagnosis of achondroplasia and spondylo epiphyseal dysplasia

The classical *achondroplastic* dwarf is dwarfed from birth Disturbance of growth of cartilaginous bones results in an absolute diminution in length with a disproportionate involvement of the proximal segments (Fig 1) The epiphyseal ossification centers are usually regular Because the facial bones and particularly the base of the skull are preformed in cartilage these structures too are involved and give the achondroplastic dwarf a characteristic bulldog face appearance In fact failure of proper development of one component of the base the foramen magnum has been associated with obstructive

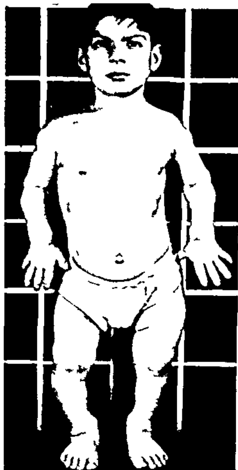


Fig 3 Spondylo epiphyseal dysplasia pseudo achondroplastic type Normal head on grotesque pseudoachondroplastic body Prominent scoliosis suggested in the stance even in the frontal photograph



Fig 4 Spine in spondylo epiphyseal dysplasia [7] The scoliosis is marked and there is gross irregularity in the mineralization of the vertebral bodies

(Figs 3 and 4 Courtesy of Amer J Roentgenol)

The study reported in this paper was undertaken originally in the belief that some of the dwarfed individuals with normal skulls and severe vertebral deformity included in MORCH s monograph actually had spondylo epiphyseal dysplasia and not achondroplasia We proposed to review available records of, and to re examine as many of this writer s patients as we could locate, and to select for study only those patients who were atypical by virtue of a normal head especially if scoliosis were prominent MORCH, who approached the problem from the point of view of human genetics, utilized clinical photographs and pedigrees for illustration reports of radiographic interpretations were included in the abbreviated case records but no reproductions of roent



Fig 5 Spondylo-epiphyseal dysplasia Irregularity of epiphyseal ossification centres (Courtesy of Amer J Roentgenol)

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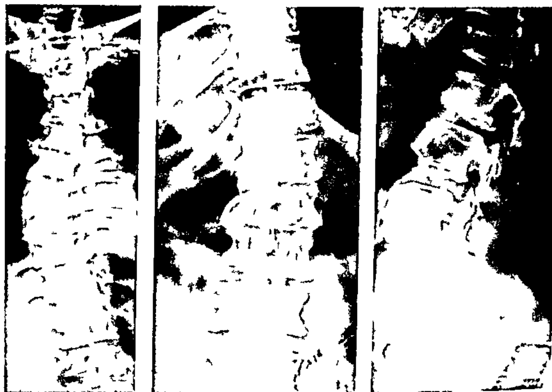


Fig 6 Spine films from 1962 of patient No 28 of MORCH Severe scoliosis and some wedging deformities of the vertebral bodies

hydrocephalus which, in some instances, has exaggerated the proportions of the parts of the cranium derived from membrane bone (Fig 2)

The vertebral column is involved in achondroplasia, but because the relative rate of growth is small in comparison with the bones of the extremities, deformities of any severe degree seldom occur Rarely, kyphosis is seen, with the hypoplastic vertebral body at the apex of the curve so wedged as to suggest a posterior hemivertebra deformity The chief findings in the spines of most achondroplastic dwarfs are related to the form of the individual bodies and the small vertebral canal which can be recognized by diminished interpedicular distances in frontal films

CAFFEY (1958) has pointed out that the sacroiliac notch of the pelvis in the classical achondroplastic dwarf is diminished This observation is a consequence of diminished growth of the portion of the ilium which extends from the ala to the roof of the acetabulum, and is a very helpful differential diagnostic point Failure of growth of this portion of the ilium probably contributes appreciably to the contracted pelvis in the affected female, which precludes normal delivery and requires cesarean section



Fig 7 Film fr m 1967 of low extrem t es of same patient as n fig 6 Th d t ils of the di p oport at in olveme t of the a ticulating surf ces (epiphyses) a bette s en



Fig 8 F l n f m 1969 of pelv f same p tient as in figs 6—7 L of art lage pace in hips coxa va a and small but not m nut sa oil c notch

In *spondylo epiphyseal dysplasia* on the contrary as pointed out by MAROTEAUX & LAMY (1959) and by subsequent writers (FORD et coll 1961) the dwarfism is seldom recognized until the second year and in some instances until the fourth or fifth year of life Examinations during the newborn period have not been reported When dwarfism is recognized the body proportions may resemble very closely those of the classical achondroplastic dwarf but the cranium has invariably been normal with no shortening of the base with no



Fig 9 Film from 1962 of skull of same patient as in figs 6—8 a) Lateral projection Normal proportions of cranial base and calvarium b) A p projection Normal foramen magnum

associated hydrocephalus, and with no depression of the root of the nose (Fig 3) Involvement of the spine has been a prominent feature with gross irregularities of mineralization and early development of progressive scoliosis (Fig 4) Extreme irregularity of mineralization of the epiphyseal ossification centers is a paramount feature of this condition (Fig 5) Finally, it has been pointed out recently (FORD et coll) that the very short sacroiliac notch described by CAFFEY as characteristic of achondroplasia is lacking in the recorded instances of spondylo epiphyseal dysplasia although there may be some shortening of the ilium in comparison with the normal due to the general disturbance in cartilaginous growth Thus, the chief differential features between achondroplasia and spondylo epiphyseal dysplasia rest on the delay in recognition of the condition, the lack of involvement of the cranium, the serious involvement of the spine and epiphyseal centers and the absence of the classical pelvic changes in spondylo epiphyseal dysplasia

RISCHBIETH did not indicate the frequency of non involvement of the cranium in achondroplasia MORCH, however found 14 per cent of his patients to have a normal skull and 16 per cent to have no depression of the root of the nose RISCHBIETH made a definite point of the lack of abnormal curvature in the spine apart from the usual lumbar lordosis in classical achondroplasia MORCH stated that, apart from the lumbar lordosis and occasional kyphosis, 'the spinal column usually is very straight with smaller curvatures than normally Ninety three per cent of MORCH s patients had no scoliosis of any kind



Fig 10 Films from 1963 of cran um in pat ent No 80 of MORCH Normal relationships of base and cal ar um a) Lateral projection b) In bas lar projection the foramen magnum is of no mal s ze

Case reports

We have been able to review the roentgenograms and re examine several of MORCH s original patients who have had normal heads with or without scoliosis These include Cases 28 58 80 and 22 In addition, we have had the opportunity to examine two daughters of the patient listed as Case 22

Case 28 Female 32 years old when studied by MØRCH in 1938 She was 56 years old when re examined for this study There had been no family history of dwarfism and the pa tient had beer born normally at term Dwarfism was first recognized at 4 years of age In 1938 the bones of the extremities were described as very short plump and robust with vigo ous muscular insertions *epiphyses very irregular* (italics ours) Irregularity of vertebral bodies was noted together with scoliosis Because of back and leg pains she had been unable to work since the age of 20 years MØRCH summarized her report with typical chondrodys trophic with normal head

Roentgenograms obtained in 1962 demonstrated spinal involvement with moderately se ere scoliosis (Fig 6) The extremities (Fig 7) showed severe distortion of the articulating ends of the bones In the pelvis (Fig 8) loss of cartilage space was noted at the hips the sacroiliac notch though short was appreciably longer than it is in achondroplasia The cranium had a normal configuration as would be expected from clinical inspection and the foramen magnum was of normal size (Fig 9)

Case 58 Female 30 years of age when studi d by MØRCH She was re examined in 1962 at the ag of 54 Her fam ly history was negative for dwarfism Although MØRCH categorized her as a typ cal chondrodystrophic he noted that the head was perfectly normal clinically and radiologically Her dwarfism was first noted at the age of 3 years Her roentgenograms were comparable at both examinations the articulating ends of the bones showed marked d stortion a prominent scol osis was pres nt and the cranium was normal The pelvis showed



Fig. 11. Films from same patient as in fig. 10. Gross irregularities of the articulating ends of bones at the knee and in the hips. The sacroiliac notches are not reduced in size.



Fig. 12. Film from 1963 of skull of patient No. 22. Normal relationships of base to calvarium.

coxa vara and osteoarthritic changes in the hips; the sacroiliac notch was shorter than normal but not so short as in achondroplasia.

Case 80. Male, 36 years old when seen by MORCH in 1940. He was re-examined at 59 years in 1963. There is no information about his age when the dwarfism was first noted. MORCH called him "atypical chondrodystrophic" though with an almost normal head. The patient had marked genu valgum; in recent years he suffered from back pain and walked with difficulty. Review of MORCH's roentgenograms (those not described in the text) and those from 1963 showed a normal cranium (Fig. 10), scoliosis with marked spondyloarthrosis, gross distortion of articulating ends of long bones (Fig. 11), and osteoarthritis of the hips with normal sacroiliac notches.

Case 22. Male, 44 years old when seen by MORCH in 1940. He was 67 when re-examined in 1963. His mother was MORCH's Case 21, who was said to have "moderate but distinct chondrodystrophy" at roentgen examination at 69 years of age, but whose head MORCH reported as "not typical" and who had other atypical features. Of interest is that the son had



Fig 13 Films from 1963 of vertebral column of *patient No 22* The spine is straight osteoarthritic lipping is present The interpedunculate distances in the lumbar spine are not unlike those seen in achondroplasia In the lateral projection the sagittal diameter of the vertebral bodies is normal and not reduced as in achondroplasia

been delivered per vaginam at home although labor had been protracted and forceps were required The age when dwarfism was first noted is not known but the patient was admitted to hospital at 7 years for osteotomies of the tibia because of severe bow leg deformity the results were poor Roentgenograms in 1940 were reported to show chondrodystrophic changes (slight degree) Clinically he was thought to have a slightly chondrodystrophic head

Review of the original roentgenograms and re-examination in 1963 showed a normal skull (Fig 12) The spine was straight but showed moderate osteoarthritic changes (Fig 13) In lateral projection the sagittal diameters of the vertebral bodies were not decreased The pelvis (Fig 14) was somewhat distorted and osteophytes were present on the iliums above the acetabulums The sacroiliac notches were small but not characteristic of achondroplasia

This patient has been married twice By his first wife he had no children By his second wife he has had five normal boys and two daughters who are short and have bow legs These daughters we shall designate Cases 22 A and 22 B

Case 22 A Female 23 years old when examined in 1964 She was 152 cm (60 inches) tall and weighed 57 kg (104 pounds) Her legs were slightly bowed and her body build suggested



Fig. 11. Films from same *patient as in fig. 10.* Gross irregularities of the articulating ends of bones at the knee and in the hips. The *sacroiliac notches* are not *reduced in size.*

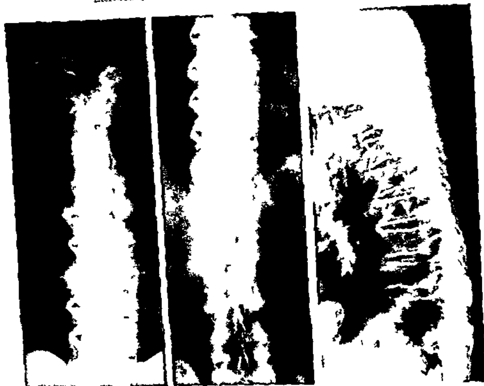


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Fig. 14. Film from 1963 of pelvis of patient No. 22. The pelvis is contracted but not typically achondroplastic. Osteophytes on the iliums above the acetabulums, on the ischiums and on the *prominent lesser trochanters* are common in vitamin D resistant rickets in later life.

disproportionately short lower extremities; her head was normal. Roentgenograms showed some bowing of all the major long bones with thickened cortex at the sites of bowing (Fig. 15). The spinal column was straight, and the pelvis was not remarkable (i.e. the sacroiliac notch was normal).

Case 22 B. Female, 14 years old when examined in 1964. She was 117 cm (46 inches) tall and weighed 30 kg (66 pounds). Her legs were severely bowed; her head was normal. Shortened stature was first noted at 4 years of age. Roentgenograms taken at 7 years as well as at 14 years of age were available. The spine was straight but the bones had a chalky density and coarsened trabecular architecture. In the skull, there was premature *synostosis* of the sagittal suture. The important diagnostic features were in the bones of the pelvis and extremities, where, in addition to coarsened trabecular architecture, the still unfused epiphyses demonstrated unequivocal signs of rickets (Figs 16, 17, 18).

Laboratory studies for the father and his younger daughter are shown in a Table I.

Table

Calcium, phosphorus and alkaline phosphatase determinations in an alleged achondroplastic dwarf and his daughter

Date	Case No	Ca	P	P'tase
5—11—64	22	9.6 mg	2.2 mg	5.8 K A units
7—13—56	22 B	10.2 mg *	3.3 mg	33.0 K A units
5—11—64	22 B	9.7 mg	1.9 mg	34.2 K A units



g 15 F lms showing long bones of patient No 2? A demonstrating res dual bowing deformities d cort cal th cken g No features of achondroplas a

Discussion

Three of the patients described above (Cases 28 58 and 80) although riginally considered as achondroplastic dwarfs by MORCH can be recognized ow as fulfilling the criteria for the diagnosis of spondylo epiphyseal dysplasia n each the recognition of the dwarfism was not made until some time after irth (3 to 4 years) In each the facial and cranial appearance is grossly hat of a normal individual In each the cranium shows no radiographic bnormalities The opportunity to examine the foramen magnum in Cases 8 and 80 permits us to state unequivocally that there are no signs of the small oramen magnum of classical achondroplasia

In each instance there was evidence of distinct involvement of the spine ith severe scoliosis The pelvis of each patient had a configuration which hough not normal was nevertheless different from that occurring in achondro plasia Unfortunately films of these individuals at times prior to epiphyseal nion are not available it is probable that they would have demonstrated ross irregularities in mineralization of the epiphyses of the type described y MAROTEAUX & LAMY in spondylo epiphyseal dysplasia In all of the three

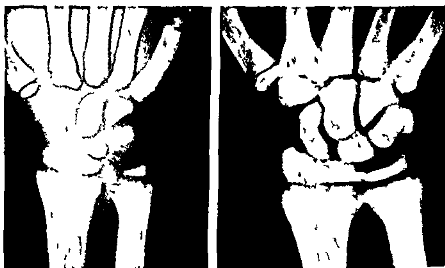


Fig 16 Wrists at 7 years and at 14 years respectively of patient No 22 B Classical signs of rickets

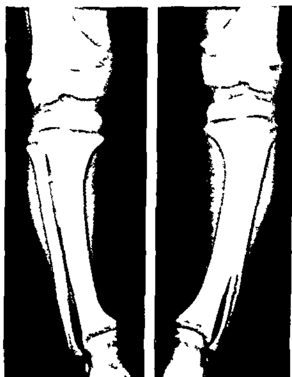


Fig 17 Lower extremities at 7 years of age in patient No 22 B



Fig 18 Films of pelvis at 7 years and 14 years of age respectively of patient No 22 B Classical signs of rickets normal sacroiliac notches

patients the articular surfaces ultimately showed gross distortion This distortion might well have arisen from defective mineralization with deformity consequent to abnormal stresses on the abnormally mineralized epiphyses

The identification of grossly irregular epiphyseal ossification centers in children whose centers are still unfused is an important diagnostic feature of spondylo epiphyseal dysplasia Unfortunately in adults irregular epiphyseal ossification can only be inferred from abnormally formed articulating ends of tubular bones Since true achondroplastic dwarfs are not notable for arthritic changes in middle age whereas individuals with epiphyseal dysplasias commonly are afflicted the argument in favor of a diagnosis of spondylo epiphyseal dysplasia finds additional support Thus we can suggest that some of MØRCH s chondrodystrophic (i e achondroplastic) dwarfs actually had another condition and therefore cannot serve as standards for the diagnosis of achondroplasia

The observation that the patient in Case 22 selected for review because of a normal head has daughters with vitamin D resistant rickets indicates another cause for confusion in the diagnosis of achondroplasia It is the rule for individuals with vitamin D resistant rickets to be stunted in growth especially if treatment has been poorly controlled Obviously the patient in Case 22 also had vitamin D resistant rickets and his low serum phosphorus in 1964 supports this opinion His mother (Case 21) also must have suffered from this disease In fact the pattern of inheritance of the condition in the three affected generations is compatible with sex linked dominant transmission which is postulated for vitamin D resistant rickets (WINTERS et coll 1958) Fifty per cent of the children of affected females may have the disease All of the daughters of affected males will be affected but none of the male offspring of a father with vitamin D resistant rickets has the condition We have extended the original pedigree of Cases 21 and 22 as shown by MØRCH to

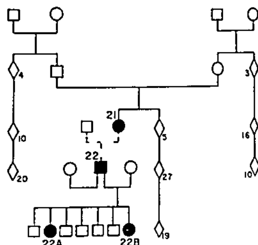


Fig. 19. Diagram of pedigree of MORCH's cases No. 21 and 22 extended to include Nos. 22 A and 22 B.

include Cases 22-A and 22 B (Fig. 19). If one were satisfied that he was dealing with achondroplasia, the autosomal dominant inheritance of this condition would seem to be reasonably well established.

It is clear that short limbed dwarfed adults may reach their definitive proportions as a result of a variety of growth defects. These include achondroplasia, spondylo epiphyseal dysplasia, and vitamin D resistant rickets. Metaphyseal dysostosis and other skeletal dysplasias also may be involved in some instances, but thus far, we have not been able to identify these conditions among MORCH's material. Ideally, the differential diagnosis of achondroplasia requires roentgenograms of skeletal structures during growth. If these are not available, the diagnosis of many of the conditions is insecure, especially if there are atypical features. This investigation has shown that diagnosis of skeletal dysplasias must take cognizance of recurring patterns of signs and symptoms, of information provided by pedigree analysis, of confusing phenocopies and overlapping genotypes, and particularly of the developmental approach inherent in pediatrics and its related subspecialities.

SUMMARY

Recent reports of syndromes which simulate achondroplasia stimulated a review of atypical cases in the classic report by MORCH. Three patients selected because of an unaffected cranium are believed to have spondylo epiphyseal dysplasia. One similarly selected the son of another of MORCH's patients has two dwarfed daughters with unequivocal vitamin D resistant rickets. Achondroplastic dwarfs with normal heads and other atypical features merit careful study properly to categorize their affection.

ZUSAMMENFASSUNG

Neue Berichte über Syndrome die Achondroplasie simulieren können waren der Anlass die atypischen Fälle aus MORCHS klassischem Bericht durchzusehen. Bei drei Patienten die wegen eines intakten Kraniums ausgewählt worden sind glaubt man dass es sich um spon

dylo epiphysare Dysplasie handelt Ein Fall der unter ähnlichen Bedingungen ausgewählt wurde und der Sohn eines von Morchs Patienten ist hat zwei wachstumsbehinderte Tochter mit sichergestellter vitaminresistenter Rachitis Achondroplastische Zwerge mit normalen Schadeln und and ren atypischen Eigenschaften verdienen zur diagnostischen Einordnung ihrer Affektion ein sorgfaltiges Studium

RÉSUMÉ

Des publications recentes sur des syndromes qui simulent l achondroplasie ont poussé les aut urs a réétudier des cas atypiques du classique travail de Morch Trois malades choisis parce que leur crâne était normal avaient semble t il une dysplasie spondylo-épiphysaire Un autre choisi pour la meme raison et fils d un autre malade de Morch a deux filles naines atteintes indubitablement de rachitisme vitamino résistant Il faut examiner soigneuse ment les nains achondroplasiques qui ont une tète normale et d autres caracteres atypiques pour clas r correctement leur affection

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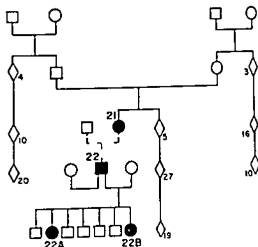


Fig 19 Diagram of pedigree of MORCH's cases No 21 and 22 extended to include Nos 22 A and 22 B

include Cases 22 A and 22 B (Fig 19) If one were satisfied that he was dealing with achondroplasia, the autosomal dominant inheritance of this condition would seem to be reasonably well established

It is clear that short limbed dwarfed adults may reach their definitive proportions as a result of a variety of growth defects These include achondroplasia, spondylo epiphyseal dysplasia and vitamin D resistant rickets Metaphyseal dysostosis and other skeletal dysplasias also may be involved in some instances, but thus far, we have not been able to identify these conditions among MORCH's material Ideally, the differential diagnosis of achondroplasia requires roentgenograms of skeletal structures during growth If these are not available, the diagnosis of many of the conditions is insecure, especially if there are atypical features This investigation has shown that diagnosis of skeletal dysplasias must take cognizance of recurring patterns of signs and symptoms, of information provided by pedigree analysis, of confusing phenocopies and overlapping genotypes, and particularly of the developmental approach inherent in pediatrics and its related subspecialities

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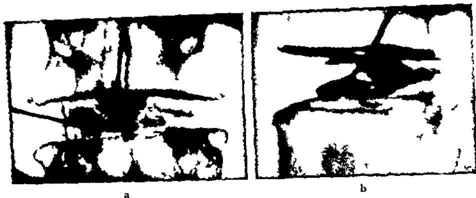


Fig 1 Extradural puncture of a disk Frontal (a) and lateral (b) projections

the puncture is made extradurally there should be no risk of arachnoiditis and headache

The introduction of roentgen television has enabled a reliable check of the position of the needle to be made in the lateral position The authors have availed themselves of this aid in the last few years to perform lumbar disk punctures extradurally from the side Since this seems to be much more simple than the transdural approach an account of the results obtained and of complications encountered may be of interest

Material Punctures directly from the side, or slightly from behind were performed in 71 patients of ages ranging from 23 to 64 years the majority being out patients Most of the patients had had sciatic or lower back pain, but a few had had urinary tract symptoms or pain in the lower part of the abdomen

Technique The patient was placed on the side or slightly prone The fluoroscopy unit consisted of a 5 inch intensifier an image orthicon camera and a monitor The skin was cleansed and covered with sterile cloths leaving the field of operation exposed however The image intensifier and the roentgen control unit were covered

The disk to be examined was located by fluoroscopy and its lateral projection on the skin was marked After local anaesthesia the puncture was performed with a needle 1 to 2 mm in external diameter provided with a mandrin The needle was inserted into the disk approximately parallel with the central ray and advanced in steps with frequent checking of its position and direction The needle was guided with great precision by pulling slightly on the skin outside the roentgen field The depth of the needle could be estimated easily

FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR THE LATE PROF K LINDBLOM), KAROLINSKA SJUKHUSET, STOCKHOLM, SWEDEN

EXTRADURAL LUMBAR DISK PUNCTURE

by

P EDHOLM, I FERNSTRÖM and K LINDBLOM

Puncture of the lumbar disks has usually been performed transdurally directly from behind, a procedure introduced by LINDBLOM in 1948. This author pointed out that the upper lumbar disks are more conveniently punctured from the side, for transdural puncture at this level is attended by a risk of damage to the conus medullaris. Those extradural punctures were not performed directly from the side but slightly from behind at an angle of 70° to 60° to the sagittal plane. A similar technique has been described by DE SÈZE (1955), who observed that Ross Codornill performed extradural punctures with a special instrument, making the injection from a more dorsal direction. Extradural punctures are, however, comparatively uncommon because in the first place the upper lumbar disks are seldom the site of symptoms, and because the conventional lateral fluoroscopic technique is an unsatisfactory means of checking the position of the needle as it is being introduced into the disk.

Complications such as arachnoiditis and diskitis have occasionally been reported following transdural puncture. A much more common sequela is headache after the examination and this has been reported in about 10% of a series of 386 cases (FERNSTRÖM 1960). The headache is probably due to leakage of cerebrospinal fluid and may be both severe and of long duration. When

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Table 1

Disk punctures performed in a total of 214 disks and 71 cases

Number of disks punctured	Number of cases	Number of disks
1	5	5
–	13	26
3	32	96
4	18	72
5	3	15
	Total 71	

Table 2

Different levels and number of punctures in relation to numbers and percentages causing symptoms

Level	Number of disks	Number of disks giving symptoms	Percentages of disks giving symptoms
Th12	2	0	0
L1	10	1	10
L2	33	5	16
L3	60	11	18
L4	64	20	30
L5	45	26	57
	Total 214		

An examination of the upper lumbar disks is also of clinical interest, since these are not seldom the source of symptoms The levels of puncture the number of punctures and the number of disks giving symptoms are recorded in Table 2 All the disks were easy to puncture except the fifth lumbar which in four cases was so difficult to enter that the lateral puncture was unsuccessful In these cases the disk was low in position and the high crest of the iliac and osteophytes on the borders of the vertebral bodies prevented the passage of the needle In one case with a low diaphragm it was necessary to abandon puncturing the L1 disk, owing to pleural pain but in all the other cases the puncture was successful

Complications Complications were noted in 5 cases in three of which diskitis was recorded 7 to 14 days after the puncture, and in all of them the appropriate treatment resulted in complete recovery There was moderate pneumothorax in one case in connection with puncture of the L1 disk the air disappeared



Fig. 2. Extradural puncture of disk at L5 using a 2 mm needle: frontal (a) and lateral (b) projections.

from its parallactic movement, on turning the patient slightly or moving the roentgen tube gently to and fro. The radiation was switched off each time the needle was advanced. A characteristic slight resistance was felt when the needle entered the disk, the needle was thereafter advanced about 2 cm into the disk (Fig. 1). The injection of the contrast medium and the registration of pain were performed and noted in the same manner as for transdural puncture.

When puncturing the fifth, and sometimes the fourth disk, it was necessary, in order to avoid the crest of the ilium, to start the puncture cranial to the disk so that its direction was not parallel with the plane of the disk. By using needles with a slight curve, however, the actual tip could be brought parallel with the plane of the disk as the latter was entered. The curved needle was sometimes too pliable to be guided in the required direction, and then a needle with an external diameter of 2 mm was preferred (Fig. 2).

Percutaneous fenestration of the disk was performed at the same examination in those cases in which the symptoms could be reproduced by diskography — in about half the number of cases in the series. A 2 to 5 mm needle was then inserted into the disk, as described above, after the diskography. These large needles are necessary for a fenestration and for removing nucleus material from the disk.

Results

Two hundred and fourteen disks were punctured in the material of 71 cases (Table 1). In 17 patients a particular disk was punctured on more than one occasion. Two punctures were performed in 12 disks, and 3 and 4 punctures respectively, in 2 disks. The total number of punctures was then 231.

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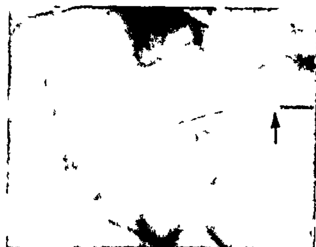


Fig. 3. Transdural disk puncture using a double needle; the outer needle is inserted only as far as the dural sac (arrow).



Fig. 4. Lateral diskogram of thoracic disk punctured extradurally.

spontaneously. In the fifth case, a paravertebral haematoma appeared during the examination, and exploration performed on the day of the puncture failed to disclose the site of haemorrhage; only 200 to 300 ml of coagulated blood were removed. The patient recovered rapidly. In no case was there headache or signs of arachnoiditis. The patients as a rule experienced little if any discomfort during the puncture, excepting that nerve pain was sometimes elicited as the needle entered the disk. This was more frequent the further dorsally the puncture was performed, and was more common in the lower disks. The patients often had slight aching and stiffness of the back for a day or two after the operation.

Discussion

It is evident from the results that it is often technically easy to puncture the four first lumbar disks from the side with a straight needle. However, a curved needle is often required in order to enter the lowermost disk but this is no disadvantage. Even with this technique there were however four unsuccessful cases. In puncture of the upper lumbar disks, the needle will not infrequently have passed through renal tissue but there was no instance of haematuria. Nor were there any symptoms of peritonitis, which might have been expected since when puncturing the lower disks the needle may enter the abdominal cavity. In puncture of the lowermost disks there is also a theoretical possibility that the common iliac artery may be entered, with major haemorrhage as a consequence. Such a complication may have occurred in

one of the cases though there was no indication of this at operation That diskitis was noted in three cases is remarkable since it occurred in only one case when the transdural method was used and then in a series 5 times as large It would therefore seem probable that in spite of rigorous measures undertaken to prevent infection the risk of diskitis is considerably greater with this method than with the transdural one

It is relevant in this connection to observe that in a series of 386 cases in which 1 518 disks were punctured by the transdural method (FERNSTROM 1960) not a single case of diskitis was noted

Two possible causes of the diskitis in the present series may be suggested Although these lateral punctures were p rformed slightly from the back the needle may have passed through the intestine so that infected material was introduced into the disk or the technique at extradural puncture may not have been the same as when the transdural method was used With the latter a double needle (Antoni needle) was employed A relatively short outer needle was inserted through the skin to the dural sac after which a fine and longer inner needle was inserted through the dural sac into the centre of the disk (Fig 3) This has the advantage that the needle entering the disk never comes in direct contact with the skin With the extradural method no such double needle was used and the needle inserted into the disk had passed through the skin The needles then used were moreover of a larger calibre and the increase in diameter resulting from the addition of an external needle would probably have complicated the operation puncture The fenestration and the biop y examinations of course involved a larger operation on the disk and the risk of infection may thus have been greater In extradural punctures intended only for diagnostic purposes it naturally should be possible to use considerably thinner needles provided with an outer needle

The advantages of the method include simplicity absence of such complications as headache and arachnoiditis which follow transdural puncture and the fact that since the dural sac is never punctured and the needle passes only through skin muscles and ligaments the patient is able to walk and move freely after the puncture furthermore the operation can be performed without admitting the patient to hospital

Symptoms may originate from the upper lumbar disk though not so often as from the lower lumbar disk (FERNSTROM 1960) The former must in any case be punctured extradurally to avoid the risk of encountering the conus medullaris It is thus chiefly in the puncture of these upp r disks that the extradural method should be used and then a double needle of the Antoni type is to be preferred In cases already op rated upon for disk herniation the anatomy is sometimes so modified that an extradural approach is then the only

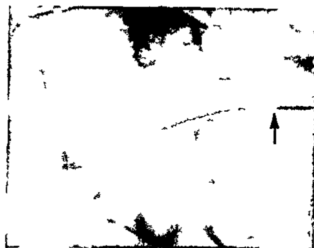


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SUMMARY

Two hundred and thirty one lumbar disk punctures were performed extradurally An account is given of the technique and the complications encountered The advantages and disadvantages of the extradural puncture and indications for the technique are discussed

ZUSAMMENFASSUNG

Lumbale Diskpunktionen wurden extradural in 231 Fallen vorgenommen Die Technik und Komplikationen werden beschrieben Die Vorteile der extraduralen Punktion und deren Indikation werden besprochen

RÉSUME

Les auteurs on fait 231 ponctions de disques lombaires par voie extra durale *Ils décrivent* la technique et les complications Ils étudient les avantages et les inconvénients de la ponction extra durale et les indications de cette technique

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FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR THE LATE PROF K LINDBLOM) KAROLINSKA SJUKHUSET STOCKHOLM SWEDEN

ANGULATIONS IN FRACTURES OF THE FEMORAL NECK WITH AND WITHOUT SUBSEQUENT NECROSIS OF THE HEAD

by

P Edholm K Lindblom and K Maurseth

It is generally believed that necrosis of the femoral head following medial fractures of the neck is caused by interference with the blood supply The present investigation was performed to determine whether angulation of the fragments after reduction and fixation by operation had any significance in the development of subsequent necrosis

Material Two groups of cases treated for medial fractures of the femoral neck during the years 1940—1958 were studied One consisted of cases with necrosis of the femoral head and the other of those without necrosis Only cases with roentgenograms of a quality satisfactory for analysis were selected

Necrosis of the femoral head was indicated when the roentgenograms demonstrated a deformity of the joint surface of the head consisting of a depression of a limited area accompanied by variations in bone density adja cent to this area Excluded were 9 cases of non union one of osteitis and 3 cases in which the quality of the films excluded evaluation of the angulation

Submitted for publication 27 August 1965

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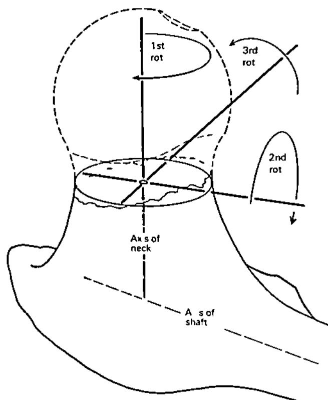


Fig 3 The three axes of the coo dinate syst m

Method The left sided fractures were studied as though they were right sided by means of their mirror images The films used in the cases operated upon were the first ones taken after fixation and in the conservatively treated cases those obtained at the first control The quality of the films in certain cases was insufficient for an evaluation of the position while in others the fracture was not consolidated The films obtained at the following control were then used

Four axes were drawn on both the a p and lateral films (see Fig 1) (I) the longitudinal axis within the upper part of the femoral shaft (II) the axis of the neck (III) the axis of the head and (IV) the axis of the fovea defined as the line between the center of the fovea and the center of the head drawn as follows (see Fig 2) the center of the fovea was marked on the films A transparent paper on which was drawn an angle and its bisector was placed

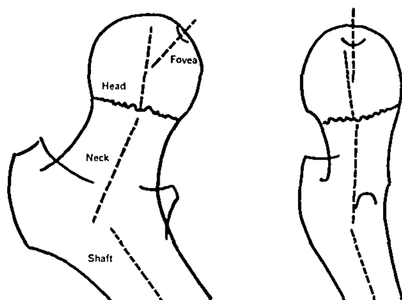


Fig. 1. The four axes in the upper femur: a.p. and lateral projection.

Four of the 31 cases accepted were treated conservatively, 26 by the JOHANSSON fixation method and one case by the von BAHR method.

Forty cases were selected for the group 'without necrosis'. They were observed for an average duration of 31 months after the occurrence of the fracture without signs of necrosis, the shortest observation time being 12 months.

Twenty six of these cases were treated by the Johansson fixation method, three by the Nystrom method and four cases by the von Bahr method. Seven cases were treated conservatively.

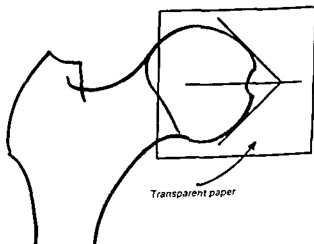


Fig. 2. Illustration of the method used for finding the axis of the fovea.

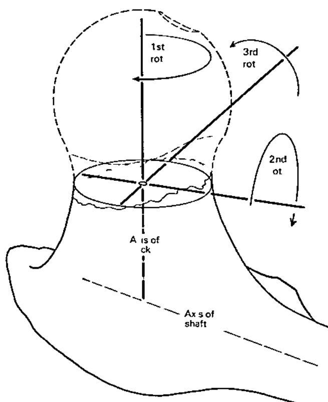


Fig 3 The three axe of the coord nate ystem

Method The left sided fractures were studied as though they were right sided by means of their mirror images The films used in the cases operated upon were the first ones taken after fixation and in the conservatively treated cases those obtained at the first control The quality of the films in certain cases was insufficient for an evaluation of the position while in others the fracture was not consolidated The films obtained at the following control were then used

Four axes were drawn on both the a p and lateral films (see Fig 1) (I) the longitudinal axis within the upper part of the femoral shaft (II) the axis of the neck (III) the axis of the head and (IV) the axis of the fovea defined as the line between the center of the fovea and the center of the head drawn as follows (see Fig 2) the center of the fovea was marked on the films a transparent paper on which was drawn an angle and its bisector was placed

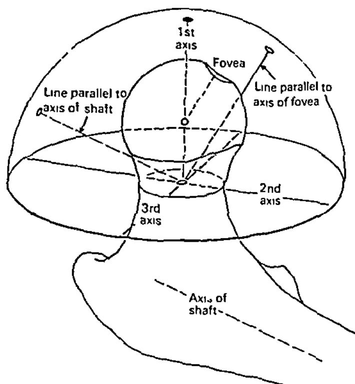


Fig. 4. The hemisphere of which the orthographic projection is used as a diagram to represent the orientation of the proximal fragment.

on the film so that both arms of the angle were tangential to the contour of the head, with the bisector passing through the center of the fovea, the bisector now corresponded to the fovea axis and was plotted on the film. The radiologist drew the three other axes from his own assessment of their probable position.

A special instrument for measuring angles enabled the orientation of the proximal fragment to be evaluated and defined in relation to an imaginary rectangular coordinate system lying in the distal fragment, with its origin at the point of intersection between the fracture surface and the axis of the neck (Fig. 3). The latter was chosen as the first axis of this system. The second axis was placed perpendicular to the first, in a plane parallel to the shaft of the femur, and the third axis perpendicular to both the first and second axes. The change in orientation of the proximal fragment caused by the fracture was described as three successive rotations about these axes. The first rotation about the axis of the neck is often referred to as the 'rotation' in contrast to the two succeeding rotations, which are usually referred to as 'angulations'. Rotation about the second axis causes anterior or posterior angulation, and rotation about the third axis produces valgus or varus angulation. Thus, in all cases the change in orientation of the proximal fragment was divided into

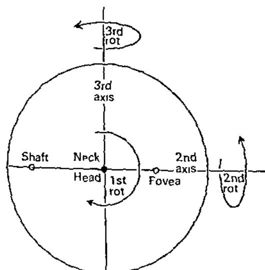


Fig 5 Orthographic projection of the hemisphere in fig 4 Directions of the axes of shaft neck head and fovea are represented as points The first axis and the axes of the head and neck coincide in the center

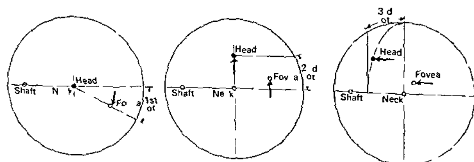


Fig 6 Diagrammatic representation of the three successive rotations of the proximal fragment The magnitude of each rotation is represented by the arcs outside the periphery First rotation about the axis of the neck (left) second rotation about the transverse axis (middle) and third rotation about the sagittal axis (right)

three components the rotation the anterior or posterior angulation and the varus or valgus angulation

For reasons of simplicity the original position of the proximal fragment was considered to have been such that the axes of the head and neck were parallel and that the axis of the fovea was parallel to the plane formed by the axes of the neck and the femoral shaft These assumptions are not quite realistic but as the problem was to compare the two groups the absolute values of the three components of rotation were of secondary interest

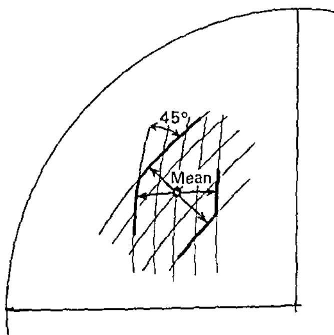


Fig. 7. Two stages in the graphic computation of a distribution dispersion. The heavy lines represent one standard deviation in four different directions.

In measuring angles from roentgenograms, the direction of the rays to the films through the apex of the angle has to be known. In all the cases selected, the direction of these rays could be estimated with sufficient accuracy from the two films. An error in assessing the direction of these rays causes only minor errors in the final result.

All measurements were evaluated statistically, the mean values and standard deviations of the rotations about the three axes being calculated, and also represented in the following manner. A circular diagram was constructed representing an orthographic projection of a hemisphere situated with its center in the line of fracture (Fig. 4), and its plane surface resting on the second and third axes in the coordinate system (the diagram being a projection in the direction of the axis of the neck). The direction of any line could now be represented in the diagram as the point of intersection between the surface of the hemisphere and a line through the center parallel to the line in question. The direction of the axis of the shaft would be represented by a point far to the left in the diagram, and the axis of the neck would be a point in the center coinciding with the first axis. If no displacement was present, the point representing the direction of the axis of the head should coincide with that of the neck in the center of the diagram, and the axis of the fovea would be a point just to the right of the center (Fig. 5). Different displacements are represented in Fig. 6. Each group of fractures was plotted on a diagram, by means of which

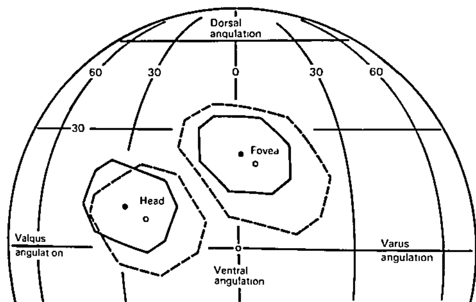


Fig 8 The orientation of the proximal fragment Broken lines and unfilled circles represent cases of necrosis and continuous lines and filled circles cases without necrosis The circles show the mean position of the axes of the head and the fovea the lines mark one standard deviation

a graphic representation of the orientation of all fractures in a group was obtained The mean direction of the axes of the head and fovea were computed and marked in the diagram

Graphical computations were performed for each distribution in order to assess the dispersions These represented the following operations on the imagined sphere of which the diagram is an orthographic projection A system of great circles was drawn at 5 intervals through a diameter of the sphere perpendicular to the line from the mean to the center The number of cases in each interval was noted The two great circles that divided the distribution at a distance of one standard deviation on both sides from the mean, were computed and arcs representing these circles drawn on the diagram The system of great circles was then rotated 45 about the mean and the procedure was repeated (Fig 7) This was continued until each distribution had eight such arcs marking the standard deviation in eight different directions from the mean (Fig 8) The diagrams were easily prepared with an instrument in which directions are represented as points on an orthographic projection of an auxiliary hemisphere

Results

The results are recorded in tabular form below.

	Group with necrosis (31)		Group without necrosis (40)	
	Mean	Stand. deviat.	Mean	Stand. deviat.
Rotation of the proximal fragment about				
the first axis	32.8	26.7	30.0	21.7
the second axis	6.3	12.8	10.4	9.9
the third axis	23.7	1[illegible]	28.9	19.3

In all rotations, the group with necrosis had a greater standard deviation than the group without necrosis although the difference was not significant. There was no noteworthy difference between the mean values of the two groups.

Thus, in this material of medial fractures of the femoral neck, no significant differences could be found in the orientation of the proximal fragment in relation to the distal fragment between a group that developed necrosis of the femoral head and a group in which this did not occur.

SUMMARY

Two series of medial fractures of the femoral neck, one with and one without subsequent necrosis of the femoral head, were examined. The angulations, measured with a special instrument, indicated no obvious differences between the groups.

ZUSAMMENFASSUNG

Zwei Serien von Fällen mit medialer Schenkelhalsfraktur, die eine mit, die andere ohne Femurkopfnekrose, wurden verglichen. Die entsprechenden Winkel wurden mit einem Spezialinstrument gemessen und kein Unterschied konnte zwischen den beiden Gruppen festgestellt werden.

RÉSUMÉ

Les auteurs ont examiné deux séries de fractures sous capitales du col du fémur, l'une avec et l'autre sans nécrose ultérieure de la tete fémorale. Les angulations, mesurées avec un instrument spécial, *ne montrent pas de différence évidente entre ces deux groupes.*

REFERENCES

EDHOLM P.: Instrument for measuring angles from roentgenograms. Acta radiol. Diagnosis 6 (1967), 156.

FROM THE ROENTGEN DEPARTMENT (DIRECTOR PROF J FRIMANN DAHL) AND THE UNIVERSITY INSTITUTE OF EXPERIMENTAL MEDICAL RESEARCH (DIRECTOR PROF F KIIL) ULLEVAL HOSPITAL OSLO NORWAY

ANGIOGRAPHY IN EXPERIMENTAL STRANGULATING OBSTRUCTION OF THE SMALL INTESTINE IN DOGS

by

TRYGVE AAKHUS

The persistently high mortality in cases of intestinal strangulating obstruction would seem to suggest lack of adequate methods of diagnosis in the early stages of the disease Clinical and conventional roentgen examinations may leave room for doubt in some cases and then result in undue delay in treatment Roentgenologic signs based on ordinary roentgenograms peroral contrast studies and pneumoperitoneograms have been described (FRIMANN DAHL 1944 MELLINS & RIGLER 1954 PERRY et coll 1956 VEST 1962) all of which appear to have certain shortcomings The impairment of the local circulation associated with strangulation indicates that angiography may be a useful tool in the early recognition of this condition PERRY et coll performed aortography in the dog with experimental strangulating obstruction of four hours duration but were unable to detect any signs attributable to the lesion In the present work the purpose was to study what angiographic changes if any are associated with experimental strangulating obstruction of the small intestine in dogs using selective superior mesenteric angiography with a serial exposure technique

Submitted for publication 16 December 1965

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Two series of medial fractures of the femoral neck, one with and one without subsequent necrosis of the femoral head, were examined. The angulations measured with a special instrument indicated no obvious differences between the groups.

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Les auteurs ont examiné deux séries de fractures sous-capitales du col du fémur, l'une avec et l'autre sans nécrose ultérieure de la tete fémorale. Les angulations mesurées avec un instrument spécial ne montrent pas de différence évidente entre ces deux groupes.

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Table 1

Angiographic findings in the experiments on strangulating obstruction and segmental venous ligature

Experiment	Localized constriction or obstruction of aa by the noose	Stagnant contrast medium in aa proximal to the noose	Stagnant contrast medium in aa beyond the noose (or in congested loop area)	Poor filling of finer arterial branches in affected loop	Poor parenchymatous density of affected loop	Generalized constriction of SMA
1 Strangulating obstruction	+	+	+	+	+	+
2 »	+	—	+	+	+	+
3 »	+	+	+	+	?	+
4 »	—	—	+	+	+	+
5 Segmental venous ligature			+	+	+	+
6 »			+	+	+	+
7 »			+	+	+	

4 *Control operation* In one dog the vessels of the selected loop were dissected free as for the experiments described in (2) above but no ligature was applied

Selective angiography of the superior mesenteric artery was performed preoperatively and at intervals during the postoperative period A roentgen opaque polythene catheter with an end hole and a preformed bend was advanced into the superior mesenteric artery through an exposed femoral artery The position of the catheter tip and the free flow in the artery were checked by the injection of a small amount of contrast medium under fluoroscopy For angiography 6 to 8 ml Hypaque 45 % were then injected during 1 5 to 2 sec by an automatic pressure syringe Lateral films were obtained with a vertical beam over a period of 10 to 15 sec with an Elema Schonander film changer The catheter was removed immediately after each examination The technical factors were 64 to 68 kV 0 04 sec 300 mA FFD 90 cm size of focal spot 1 2 × 1 2 mm

The systemic blood pressure was registered through an indwelling polythene catheter in the brachial artery or through the roentgen opaque catheter immediately prior to each angiography Clotting in the catheters was prevented

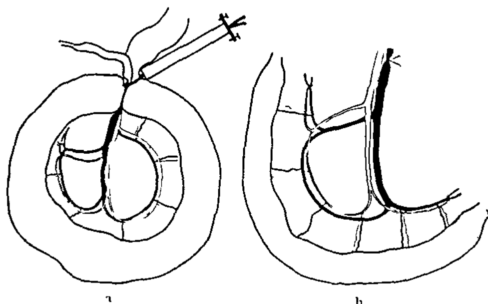


Fig 1 Schematic drawing of experimental strangulating intestinal obstruction (a) and of segmental venous ligature (b)

Material and Methods

Mongrel dogs weighing 13 to 23 kg were anesthetized with Nembutal 25 mg/kg bodyweight with supplementary doses throughout the experiments Laparotomy was performed through a midline or flank incision A bowel loop, 30 to 60 cm in length, close to the transition to the lower quarter of the small intestine, was selected for the experiments

1 *Intestinal strangulating obstruction* (Fig 1 a) The bowel loop with its mesentery was strangulated by a rubber noose in four dogs this was tightened until venous engorgement and cyanosis were observed in the region beyond the noose, but care was taken to see that arterial pulsation was still present

2 *Segmental venous ligature* (Fig 1b) The venous drainage of the loop was totally occluded in three dogs To do this the intestinal veins in the mesentery as well as the arcuate veins adjacent to the bowel wall were ligated Because of the technical difficulty of separating the veins from arteries the arcuate veins and arteries were tied at the same time

3 *Ligature of the superior mesenteric vein* In one dog the superior mesenteric vein in its lower part, corresponding to the venous drainage of the lower 1 metre of the ileum and the first part of the colon, was ligated The marginal arcuate vessels were left intact



Fig 3 Examinations of same dog as in fig 2 a) Strangulating obstruction half an hour after operation Varying constriction of the arteries at site of noose (→) slightly delayed filling of the intestinal arteries in the strangulated area (↣) b) Two seconds later Stagnation of contrast medium in one artery proximally to the noose (→) and in intestinal arteries in strangulated r (→) pseudo-tumour starting to form c) Eight hours after operation Some arteries occluded by the noose (→) delayed arterial filling in the strangulated area (↦) marked pseudo-tumour generalized constriction of superior mesenteric artery (figs 2a and 3) d) Seven seconds later Stagnation of contrast medium in arteries in strangulated area no filling of finer branches and no parenchymatous contrast density of strangulated loop distinct parenchymatous phase in bowel proximal to the strangulated loop



Fig 2 Preoperative selective angiography of superior mesenteric artery arterial phase (a) and two seconds later parenchymatous and venous phases (b)

by flushing with small amounts of heparinized saline In one dog with segmental venous ligature, no examination was made until 6 hours after operation to exclude the possible influence on the angiographic appearances of previous injections of heparin and contrast medium (dog No 7, Table 1)

Contrast injections, exposures, and systemic blood pressure were recorded on a Sanborn multichannel recorder

The abdomen was reopened at the termination of the experiments and the appearances of the abdominal organs were noted Post mortem mercury injection studies of the superior mesenteric artery were performed to aid in the recognition of the strangulated loop and its arteries in the angiograms

Results

Roentgenology The angiographic findings in the experiments on strangulating obstruction and segmental venous ligature are summarized in Table 1

In three of the dogs with experimental strangulating obstruction, serial angiography revealed an increasing degree of arterial obstruction at the level



Fig 3 Examinations of same dog as in fig 2 a) Strangulating obstruction half an hour after operation Varying constriction of the arteries at site of noose (→) slightly delayed filling of the intestinal arteries in the strangulated area (↣) b) Two seconds later Stagnation of contrast medium in one artery proximally to the noose (→) and in intestinal arteries in strangulated area (→ pseudo-tumour starting to form c) Eight hours after operation Some arteries occluded by the noose (→) delayed arterial filling in the strangulated area (↣) marked pseudo-tumour generalized constriction of superior mesenteric artery (figs 2a and 3a) d) Seven seconds later Stagnation of contrast medium in arteries in strangulated area no filling of finer branches and no parenchymatous contrast density of strangulated loop distinct parenchymatous phase in bowel proximal to the strangulated loop



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Roentgenology The angiographic findings in the experiments on strangulating obstruction and segmental venous ligature are summarized in Table I

In three of the dogs with experimental strangulating obstruction, serial angiography revealed an increasing degree of arterial obstruction at the level



Fig. 3. Examination of same dog as in fig. 2. a) Strangulating obstruction half an hour after operation. Very strong constriction of the arteries at site of noose (—→); slightly delayed filling of the intestinal arteries in the strangulated area (↣). b) Two seconds later. Stagnation of *contrast* medium in one artery proximally to the *noose* (—→) and in intestinal arteries in strangulated area (↣); pseudo-tumour starting to form. c) Eight hours after operation. Some *arteries* occluded by the noose (—→); delayed *arterial filling* in the strangulated area (↣); marked pseudo-tumour; generalized constriction of superior mesenteric artery (*figs. 2a and 3a*). d) Seven seconds later. Stagnation of *contrast* medium in arteries in strangulated area; *no filling of finer* branches and no parenchymatous *contrast* density of strangulated loop; distinct parenchymatous phase in bowel proximal to the strangulated loop.



Fig. 4. a) Strangulating obstruction sixteen hours after operation. Cessation of flow at the site of strangulation (arrow). b) Seven seconds later. Stagnation of the contrast medium in artery proximally to the noose (arrow).

of the noose (Figs 3a, 3c, and 4a). In two of these, stagnation of the contrast medium was noted in the arteries immediately proximal to the point of compression (Figs 3b and 4b). The blood flow was distinctly reduced in the strangulated area, even in the case without any visible compression of the arteries. This flow reduction resulted in a delayed and prolonged outlining of the arteries, a poor filling of finer arterial branches, and only a slight parenchymatous contrast density in the strangulated loop (Fig. 3).

All signs varied considerably in relation to the time, as is evident from Fig. 3. The signs in some examinations were more or less obscured by superimposed normal bowel. However, in all the four experiments one or more signs were demonstrated at all stages. Table 1 gives a sign as present if it were noted at one stage or another, even if not throughout the whole experiment.

The arterial flow into the affected area was reduced in all the three experiments on segmental venous ligature. A characteristic delayed and prolonged outlining of the arteries as well as poor filling of the finer branches and reduced parenchymatous density in the affected loop were clearly demonstrated (Fig. 5).

Progressive generalized narrowing of the entire superior mesenteric artery and its intestinal branches appeared in later stages (Figs 2a, 3a, and 3c) in strangulating obstruction and segmental venous ligature and this was apparent even allowing for some normal fluctuation in arterial calibre (Table 2). The consequent flow reduction in the superior mesenteric artery resulted in an

Table 2

Arterial blood pressure and arterial calibres throughout the experiments

Experiment No	Measurements	Preoperative control	Hours after operation 1/2	4	6	8	10	16	72
1 Strangulating obstruction	SMA	6 2	5 3	3 5		3 5			
	IA	2 0	1 4	1 3		1 4			
	BP	160/115	165/100	115/75		110/75			
2 »	SMA	4 3	5 3	4 5			3 8		
	IA	2 0	1 8	1 2			1 2		
	BP	165/120					115/90		
3 »	SMA	7 1	6 0			4 5	4 2	4 0	
	IA	3 0	2 6			2 0	2 4	2 0	
	BP	215/150				170/140	140/110	65/45	
4 »	SMA	5 2	5 7		4 7	4 1			
	IA	2 3	2 4		1 7	1 4			
	BP	180/140			170/130	175/110			
5 Segment l venous ligature	SMA	4 0	3 4	3 2		3 2			
	IA	1 7	1 3	1 0		1 0			
	BP	170/135	115/85			70/50			
6 »	SMA	4 9	4 6	4 4		3 3			
	IA	2 3	1 8	1 3		1 3			
	BP	140/105	115/85	85/60		15/10			
8 Superior mesenteric vein ligature	SMA	4 4	5 2			4 7			5 4
	IA	1 9	2 2			1 5			1 6
	BP	175/120				140/115			
9 Control operation	SMA	5 4	5 0		5 0				
	IA	2 1	1 8		2 0				
	BP	160/130	150/125		155/125				

SMA — diametre of superior mesenteric artery (in mm) IA — diametre of intestinal artery (in mm) and BP — systemic blood pressure (mm Hg) The diametre of the SMA was measured immediately proximal to the origin of its first branch the diametre of one IA outside the affected area was measured at a point near its origin identifiable throughout the experiment The calibre figures are the means of three measurements

increasing aortic reflux of contrast medium The parenchymatous contrast density of the entire bowel was consequently also reduced in the later stages

Following ligature of the superior mesenteric vein a slight arterial flow reduction was noted in the corresponding region at 0 5 hours postoperatively No changes from the preoperative angiography, apart from the derangement of the arteries following the manipulation of the bowel were observed in the later stages of this experiment and following the control operation

The demonstration of the veins was too poor in all the experiments to permit of any conclusions



a b

Fig 4 a) Strangulating obstruction sixteen hours after operation Cessation of flow at the site of strangulation (arrow) b) Seven seconds later Stagnation of the contrast medium in artery proximally to the noose (arrow)

of the noose (Figs 3a, 3c, and 4a) In two of these, stagnation of the contrast medium was noted in the arteries immediately proximal to the point of compression (Figs 3b and 4b) The blood flow was distinctly reduced in the strangulated area, even in the case without any visible compression of the arteries This flow reduction resulted in a delayed and prolonged outlining of the arteries, a poor filling of finer arterial branches, and only a slight parenchymatous contrast density in the strangulated loop (Fig 3)

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Progressive generalized narrowing of the entire superior mesenteric artery and its intestinal branches appeared in later stages (Figs 2a 3a, and 3c) in strangulating obstruction and segmental venous ligature, and this was apparent even allowing for some normal fluctuation in arterial calibre (Table 2) The consequent flow reduction in the superior mesenteric artery resulted in an

Discussion

In strangulating obstruction, the vessels of the loop are more or less compressed by the extrinsic band. The veins and lymph vessels are readily occluded while the arterial blood pressure may to some extent preserve the patency of the arteries. The consequent venous congestion will cause a progressive reduction of the arterial inflow. After complete venous obstruction has occurred, a slight arterial inflow may be maintained due to the loss of fluid through the capillary walls. On the other hand, the consequent rise in tissue tension constitutes an increasing impediment to flow by compression of the small vessels. Furthermore, traction and edema at the site of the strangulating band will impede the flow by a gradual mechanical compression of the arteries. The consequent reduction of the blood flow in the strangulated area may logically explain the present angiographic findings. This also implies that the angiographic appearances change in relation to the gradual flow reduction. It should be noted, however, that definite signs of strangulating obstruction were noted in the early as well as the late stages.

The experiments on segmental venous ligature revealed that the characteristic delayed selective demonstration of the arteries in the strangulated area could be caused by venous congestion alone. However, slight venous congestion may obviously exist without causing any arterial flow reduction observable by angiography, as was indicated by the experiment on ligature of the superior mesenteric vein.

The stagnation of contrast medium in the arteries proximal and distal to the strangulating noose, as well as the poor parenchymatous filling of the strangulated loop, varied with the flow reduction in each case. This emphasizes the importance of a selective angiographic method that enhances the degree of contrast density as well as a serial exposure technique that provides films in all phases. The generalized superior mesenteric artery constriction in the late stages resulted in a reduced blood flow and poor parenchymatous contrast density in the entire bowel. The difference in parenchymatous density between strangulated and normal bowel thus usually became insignificant in the late stages.

The strangulated loop was heavily congested and haemorrhagic in all the experiments with absent or definitely delayed and prolonged arterial filling in the affected area. These angiographic signs are thus indicative of severe circulatory impairment.

The generalized constriction of the superior mesenteric artery in the present experiments is not necessarily directly associated with strangulating obstruction. Mesenteric vasoconstriction has been demonstrated in animals with



a b

Fig. 5. a) Segmental venous ligature eight hours after operation. Slightly delayed filling of intestinal artery in the congested area (⟶). b) Two seconds later. Stagnation of contrast medium in the intestinal artery in the congested area (⟶).

Systemic blood pressure. The general condition of the animals was estimated from the blood pressure readings. A rapid fall in systemic blood pressure followed the segmental venous ligature, as is evident from Table 2. A slower fall was noted in strangulating obstruction. The dog with ligature of the superior mesenteric vein also had some reduction in blood pressure at eight hours, but survived. No definite fall in blood pressure occurred in the dog subjected to the control operation.

Gross pathology. The dogs with strangulating obstruction or segmental venous ligature died from their lesion or were sacrificed at a late stage of the experiment. Dark blood stained fluid was present in the peritoneal cavity and bowel lumen in all of them and the affected bowel and its mesentery were heavily congested and hemorrhagic. The affected loop was tensely dilated and elongated in the dogs with strangulating obstruction. The adjacent bowel was moderately dilated proximally but contracted distally.

In the animal with ligature of the superior mesenteric vein slight cyanosis of the affected bowel was noted at the termination of the experiment. No terminal inspection of the abdominal cavity was performed in the dog undergoing control operation. Both these two dogs survived.

Discussion

In strangulating obstruction, the vessels of the loop are more or less compressed by the extrinsic band The veins and lymph vessels are readily occluded while the arterial blood pressure may to some extent preserve the patency of the arteries The consequent venous congestion will cause a progressive reduction of the arterial inflow After complete venous obstruction has occurred a slight arterial inflow may be maintained due to the loss of fluid through the capillary walls On the other hand the consequent rise in tissue tension constitutes an increasing impediment to flow by compression of the small vessels Further more traction and edema at the site of the strangulating band will impede the flow by a gradual mechanical compression of the arteries The consequent reduction of the blood flow in the strangulated area may logically explain the present angiographic findings This also implies that the angiographic appearances change in relation to the gradual flow reduction It should be noted however that definite signs of strangulating obstruction were noted in the early as well as the late stages

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The generalized constriction of the superior mesenteric artery in the present experiments is not necessarily directly associated with strangulating obstruction Mesenteric vasoconstriction has been demonstrated in animals with

experimental cardiac arrhythmia and shock states, and has been suggested as the cause of bowel necrosis in some clinical cases (CORDAY et coll. 1962, GOODING & COUCH 1962). In support of this suggestion a distinct generalized constriction of the superior mesenteric arterial bed was revealed by angiography in cases of intestinal infarction due to embolism and possibly associated with cardiac disorders (AAKHUS & BRABRAND 1967). The concomitant decrease in arterial calibre and blood pressure in the present experiments suggests that the vasoconstriction is a shock compensating mechanism.

The anatomical arrangement of the arteries may be important in the angiographic evaluation in clinical cases of strangulating obstruction. However, this was outside the scope of the present investigation as the operative procedure itself caused considerable anatomical derangement of the arteries. The anatomical difference between the mesenteric vascular beds in man and dog (DIRR & NOER 1919) as well as non related diseases in man, e. g. atherosclerosis, *may invalidate a direct comparison between experimental and clinical* findings. It seems reasonable, however, in spite of these objections to assume that angiographic signs in line with the present experimental findings may be found in human cases of strangulating intestinal obstruction. The diagnostic value of angiography is therefore now being explored at this centre in human subjects with possible intestinal strangulating obstruction.

SUMMARY

Experimental strangulating obstruction of the small intestine in dogs was followed by selective superior mesenteric angiography preoperatively and at intervals during the post operative period. The findings are discussed in relation to the circulatory impairment in this condition. The clinical implications are briefly considered.

ZUSAMMENFASSUNG

Strangulierung und Verschluss des Dünndarmes wurden an Hunden experimentell hervorgerufen. Danach erfolgte selektive Angiographie der Arteria mesenterica superior vor Operation und bei Zeitintervallen während der postoperativen Periode. Die Resultate werden unter besonderer Berücksichtigung der verursachten Blutversorgungsstörung diskutiert und die klinische Bedeutung der Befunde wird kurz erörtert.

RÉSUMÉ

L'auteur a fait des angiographies sélectives de l'artère mésentérique supérieure du chien avant l'opération et à des intervalles pendant la période post opératoire après occlusion intestinale expérimentale par strangulation du grêle. Il en examine les résultats en fonction de la gêne circulatoire dans cette affection et en étudie brièvement les conséquences cliniques.

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VEST B Roentgenographic diagnosis of strangulating closed loop obstruction of the small intestine Surg Gynec Obstet 115 (1962) 561

experimental cardiac arrhythmia and shock states, and has been suggested as the cause of bowel necrosis in some clinical cases (CORDAY et coll 1962, GOODING & COUCH 1962) In support of this suggestion a distinct generalized constriction of the superior mesenteric arterial bed was revealed by angiography in cases of intestinal infarction due to embolism and possibly associated with cardiac disorders (AAKHUS & BRABRAND 1967) The concomitant decrease in arterial calibre and blood pressure in the present experiments suggests that the vasoconstriction is a shock compensating mechanism

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR: S. R. SJÖGREN), ST. ERIKS SJUKHUS, STOCKHOLM, SWEDEN

RETROGRADE PHLEBOGRAPHY OF BOTH ADRENAL VEINS

A preliminary report

by

C. G. MIKAELSSON

The adrenal glands are usually examined by arterial angiography, sometimes after previous injection of adrenalin to cause the normal vessels to contract. Because of the widely differing anatomy of the small supplying arteries, these can generally be studied only by aortography. Normal intraglandular vessels, and consequently any small changes, are usually difficult to demonstrate by these methods, however, or by retroperitoneal gas insufflation. Small tumours will not be revealed unless they deform the glands, while pads of fat and organs close to the glands, may falsely be taken for tumours (FAGERBERG 1958, FRANZEN 1958). Small, relatively poorly vascularized, hormone producing tumours may exist, and it is known that neoplasms as small as peas can cause fatal hypertension (CONN et coll. 1966). Selective retrograde angiography of the adrenal veins may be of value in such cases. Catheterization of these veins is necessary if blood is to be collected for quantitative analysis of the hormones, which may also be of importance for the diagnosis.

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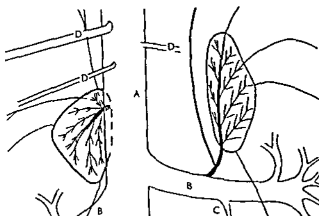


Fig 1 Sketch of the adrenal venous drainage in man (adrenal veins with veins from the diaphragm and perirenal space are in black) A — inferior vena cava B — renal veins C — left spermatic (ovarian) vein D — hepatic vein

Catheterization of the left adrenal vein for phlebography was described by BUCHT in 1962 Catheterization of the right adrenal vein for hormone analysis was also reported but the position of the catheter was not verified roentgenologically and useful films have not been demonstrated

The present author has succeeded fairly regularly in examining the right adrenal vein on injection of contrast medium, and the series now comprises 21 cases nine of which were healthy subjects Catheterization was in all cases attempted on both sides it was successful on the left side in 19 cases and on the right in 18 Seven adrenal veins have been injected at autopsy from their openings at the inferior vena cava or at the renal vein

The *anatomy* of the venous system of the glands was described in 1961 by MERKLIN & EGER among others

One or sometimes a few central veins with regularly arranged branches exist in the adrenal glands and these veins in their turn receive feeder streams There are communications between these veins and different venous net works with veins from the renal capsule the perirenal space and the diaphragm If there are several *central* veins these will run together into an outflow vein, on the left side terminating in the cranial part of the renal vein at some distance from the *inferior* vena cava generally immediately to the left of the spine (Fig 1) The outflow vein usually collects some veins from the diaphragm and the fibrous capsule of the kidney

A short outflow vein runs from the right adrenal gland and receives several tributaries often arranged *in the* shape of a broom These are fed by other veins as in the opposite gland The communication with the superficial venous net work and other veins is also *similar* to the arrangement on the other side The

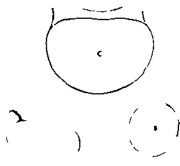


Fig 2 Sketch of cross section of spine aorta and inferior vena cava at the level of the right adrenal vein (black) A — inferior vena cava B— aorta C — Th 12

outflow vein is directed more or less in a cranial direction and receives parietal veins from this region before terminating in the inferior vena cava The cross section of the inferior vena cava is somewhat flattened, and the adrenal vein often terminates dorsally in relation to where its diameter is largest (Fig 2) The anatomy is surprisingly constant Only one drainage vein from each suprarenal body has been demonstrated The whole venous system of the glands can be filled, both at venography and in specimens, by its retrograde distension This was also demonstrated by MERKLIN & EGER in 105 specimens (of 57 right and 48 left glands) No anastomoses with the hepatic veins have been observed but on one occasion autopsy revealed a small hepatic vein that ran with the right adrenal vein into the inferior vena cava

Technique

Catheterization of the left adrenal vein is performed as follows A yellow Ödman Ledin catheter, the tip of which has a conventional bend of rather large radius, is introduced by the Seldinger method into the left renal vein via the right femoral vein The tip of the guide is then pushed past the mouth of the catheter the guide is kept in position while the catheter is withdrawn and replaced by another, the tip of which is S shaped and can be directed towards the mouth of the adrenal vein The vein is located by carefully pushing the guide out of the opening of the catheter When the guide enters the little vein the catheter follows, and the guide is then withdrawn

Catheterization of the right adrenal vein The termination of the tiny vein from the right adrenal gland at the inferior vena cava is difficult to reach with a catheter bent in the usual way In a previous communication (MIKAELSSON 1965) a catheter was described which was intended for selective catheterization of the branches of the abdominal aorta This catheter has been used twice for catheterization of the right adrenal vein but it has the drawback of being



Fig 3 Catheters in the inferior vena cava a) Straight tip in steeply directed right adrenal vein both contrast filling and blood collecting would be difficult b) Tip directed downwards pulled into steeply directed right adrenal vein c) The same shape of tip fits well even into a more transversely directed vein

difficult to use for blood sampling The first hole seems to have a tendency to close against the wall of the vein when the fluid pressure in the catheter falls below that in the vein

A new type of catheter which looks almost like a large somewhat angular loop has now been designed (Fig 3) By bending the extremity of the tip a little downwards the catheter becomes better suited to the different directions of the vein The material in the catheter is polythene gauge 240 and at the tip it is adapted to Seldinger s guide No 205 The end should be as regular and soft as possible because the adrenal veins are extremely fragile The large loop makes the catheter resilient against the wall of the vein so that the risk of trauma is reduced

A catheter of larger diameter PE No 280 has recently been tried in order to achieve a more effective obstruction to the flow of the adrenal vein and thus obtain a more complete retrograde filling of the vessels in the gland This catheter is rather stiff but to remedy this disadvantage the material is stretched so that the tube diameter and the wall thickness are reduced in part of the loop The original diameter is retained for the stem and for a small section of 5 mm immediately close to the tip which is bent a little downwards as before (Fig 4d) The catheter is inserted under monitor control in the usual

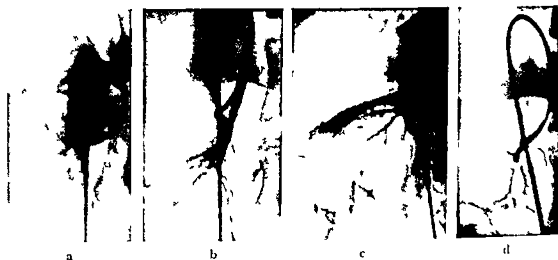


Fig 4 Right side normal a) Catheter with straight tip fairly complete filling of the adrenal gland b) Catheter with straight tip gland incompletely filled c) Fine catheter the upper part of which is hidden behind the contrast medium in the inferior vena cava d) Large catheter the venous system became almost completely filled with 3 ml contrast medium no medium in inferior vena cava



Fig 5 a) Left side normal gland b) Left side The veins are displaced by an expanding process an aldosterone producing Conn s tumour 2 cm in diameter (verified at operation see arrows) c) Left side Less complete filling two intraglandular veins displaced by a tumour of similar kind and size (verified at operation see arrows)

way via the right femoral vein and is filled with a contrast medium, such as Urografin 60 % The tip is usually turned in one of the renal veins and the loop form regained In seeking the right adrenal vein, the catheter should be pushed up above the vein opening (usually at or a little below the level of the

10th rib) and subsequently pulled down again, when it becomes fixed, the loop will be somewhat deformed. The position is judged by a test injection, and when the correct vessel has been found the catheter position should if necessary be further adjusted so that there is flow in both directions. The adrenal veins may be recognized apart from their anatomy by their sensitivity to an increase in intravasal pressure. The retrograde injection produces pain in the back and sometimes transient hypertension. The blood pressure should be controlled repeatedly while the catheter remains in an adrenal vein.

The phlebographies have generally been carried out with the Valsalva manoeuvre, i. e. at increased bronchial pressure. Its effect is judged by the pulse and the injection is begun when the pulse begins to disappear. A dose of 3 to 10 ml Urografin 60 % has been employed, the amount of contrast medium and the injection speed have been adapted to the filling and overflow into the inferior vena cava at the test injection.

Blood for hormone analysis could usually be collected. The titration values (cortisol) indicated that the blood from the right adrenal vein had been somewhat diluted by blood in the inferior vena cava. (No values for the PE 280 catheter are as yet available.) The values on the left side have varied between 2 180 to 222 units and on the right between 678 to 150 units, the fluctuation in the inferior vena cava has been between 150 to 13 units. There was one complication, but the clinical signs of thrombosis of the right iliac vein disappeared after a few days.

SUMMARY

The investigation of the right and left adrenal glands by retrograde selective contrast filling of the adrenal veins in a material of 21 cases is discussed and a new type of catheter is described.

ZUSAMMENFASSUNG

Eine Methode zur retrograden Kontrastdarstellung der rechten und linken Nebennieren durch selektive Fullung der Nebennierenvenen wurde an 21 Fallen erprobt, ein neuartiger Katheter fur diese Untersuchungen wird beschrieben.

RESUME

L'auteur étudie sur 21 cas l'examen des surrénales droite et gauche par injection de contraste retrograde sélective dans les veines surrénales et décrit

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FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR PROF OLLE OLSSON)
LUND UNIVERSITY HOSPITAL SWEDEN

FLUOROGRAPHY OF THE GASTRODUODENAL TRACT

A comparative study with 70 mm film

by

J KAUDE

The roentgenologic examination of the gastroduodenal tract generally includes fluoroscopy and filming The greatest possible accuracy in the diagnosis should of course be obtained with the least possible radiation dose The use of an image intensifier with television increases the efficiency of fluoroscopy and thus helps to reduce the dose but conventional filming continues to be the principal method of recording the information from the roentgen examination Reduction in film size leads to decreased film costs reduces the need for storage space and also the amount of assistance needed during the examination Previous efforts to replace full size films in examinations of the stomach and duodenum seem to have failed due to the relatively high dosages employed The introduction of image intensification however and the availability of 70 mm cameras have lately facilitated the trial of small film fluorography

We have used the following equipment in our department The image is recorded on the output screen of an image intensifier which is equipped with an image distributor to which other optical units may be connected such as a 70-mm spot film camera a television chain and a 35 mm cine camera Two of

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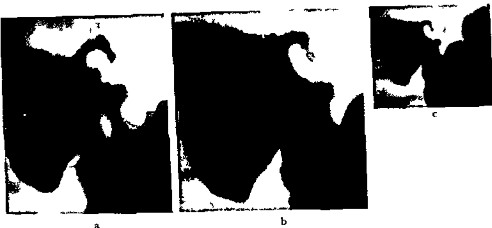


Fig 2 Pyloric ulcer Full size film (a) *70 mm film enlarged approx 3 to 4 times to correspond* to size of full size film (b) and 70 mm film in its original size (c)

tion power of 70 mm fluorography is inferior to conventional roentgenography but may be improved by the use of geometric enlargement HOLM (1964) investigated more thoroughly the resolution power of 70 mm and ordinary films utilizing the modulation transfer concept He confirmed that the image quality of the former would be suitable for clinical examinations

Present investigation

The experimental studies mentioned above indicate the possibility of replacing full size roentgenograms by 70 mm films Clinical investigations with comparison of the diagnostic accuracy appear not to have been previously reported The purpose of the present investigation has been to use 70 mm fluorography in routine examinations of the stomach and duodenum in order to determine whether picture quality was adequate and provided sufficient information for establishing a correct diagnosis It was felt that small gastric and duodenal ulcers frequently found in this common study would be suitable for testing the definition obtained and the diagnostic possibilities of the method

Comparative phantom studies supplementing HOLM's (1964) investigation and a report on the measurement of radiation doses will be discussed in separate papers A comparison of conventional radiography and 35 mm cinefluorography and a comparison of ulcer changes recorded by all three methods will be presented in subsequent papers

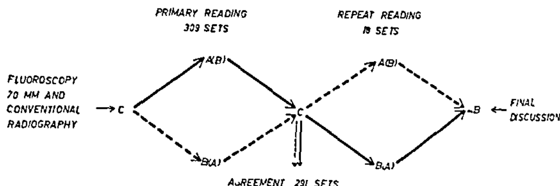


Fig. 1. Schematic drawing showing the plan of the study program.

these accessories may be selected for simultaneous operation. Thus, 70 mm exposures can be made (or cinefluorography) without the interruption of fluoroscopy via the television chain.

Previous reports. The first report on the use of a 70 mm camera in connection with an image intensifier for roentgen examination seems to be the one by JANKER (1954). FEDDEMA (1960, 1962) recommended 70 mm fluorography with a 9" image intensifier mounted on a remotely controlled ring stand. OLSSON & HOLM (1962), as well as FEDDEMA (1962), emphasized that the small film fluorographic picture quality can be improved by the use of geometric enlargement, microfocus tubes and better film material. Reduction of the radiation dose has been considered to be the main advantage of 70 mm fluorography (SIMON & GREENBERG 1963). OLSSON (1964), in a preliminary report on the comparison of image quality of full size, 35 mm and 70 mm films, pointed out that even very small ulcerative lesions in the gastroduodenal tract could be demonstrated by all three examination methods. SAMUEL & SUMERLING's (1961) approach to the problem of 70 mm films was motivated mainly by rising film costs. Their report included phantom studies, measurements of radiation dose and preliminary clinical experiences with a 70 mm camera equipped for sequence operation. BEHANBAUM & LIGNON (1964) used a Hulcher 70 mm camera in routine gastrointestinal examinations. They emphasized the important reduction in the radiation dose and the value of obtaining a large number of serial 70 mm films but insisted upon additional conventional films for a complete study of the gastroduodenal tract.

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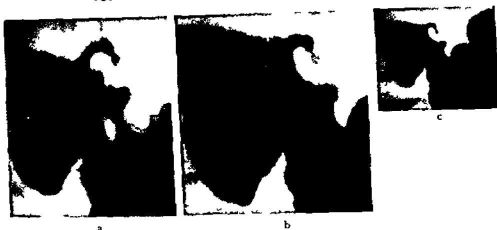


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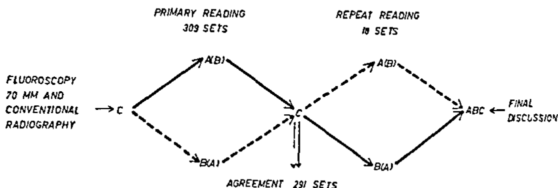


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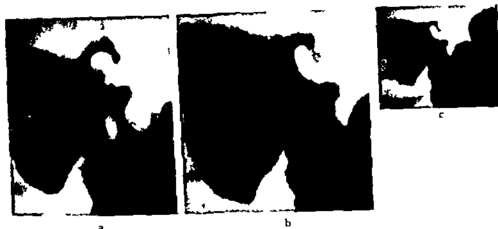


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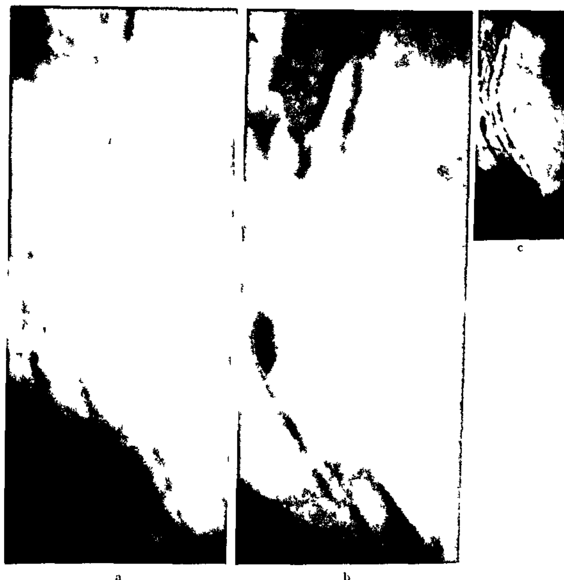


Fig. 3. Oesophageal varices. Full size film (a), 70 mm film enlarged about 3 to 4 times to correspond to full size film (b), and 70 mm film in its original size (c).

Material and Method. Three hundred and twenty random patients of both sexes with gastrointestinal symptoms were selected for this comparative investigation. The 'flow' of the study was planned after discussion with the Institution of Statistics of Lund University (Fig. 1). The examination included fluoroscopy by means of an image intensifier with television, and conventional



F g 4 H atus hern No grid used Full s ze film (a) 70 mm film enlarged (b) and 70-mm film in its o ginal size (c)

and 70 mm recordings carried out by the same radiologist All films were obtained as part of the routine gastrointestinal examination

Each complete examination was performed with the patient erect prone



F g 5 Duod n l ul at on No grid used Full ze film (a) enla g d 70 mm film (b) nd 70 mm film n o g nal siz (c)

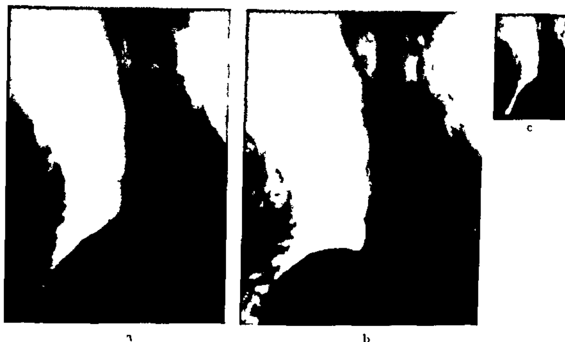


Fig. 6. Small ulcer on lesser curvature of the stomach. 70 mm film without magnification technique. The depth of the lesion was measured 1 mm on the full size film. Full size film (a), enlarged 70 mm film (b), and 70 mm film in its original size (c).

and supine. Patients in poor general condition or with profuse melaena were examined only recumbent. An effort was made to record the same information on both the conventional and the 70 mm films. As far as possible, films of both sizes were exposed in immediate sequence, with the patient in the same position, with same amount of contrast medium in the stomach or duodenal bulb, and the same compression applied.

The fluoroscopic findings were available to the two senior radiologists and full size films were read immediately by one of them. If necessary, supplementary fluoroscopic examination was carried out, and additional films were obtained in order to augment the information. The results of the readings were immediately reported, typed and signed.

The 70 mm films were usually read the next day by the second senior radiologist, who was unaware of the results of the conventional study. Both senior radiologists frequently interchanged their duties, an approximately equal number of examinations of both sizes were surveyed by each reader but during a short period of the time one of them was replaced by a third experienced radiologist. The radiologist who did the fluoroscopy (the present author)

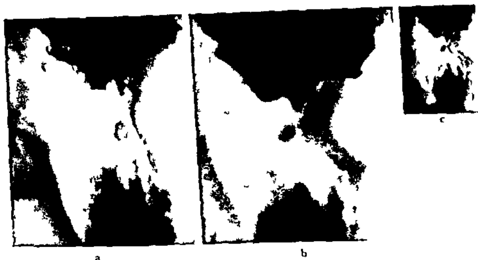


Fig 7 Ulceration of the posterior wall of the stomach 70 mm film without magnification technique Full-size film (a) enlarged 70-mm film (b) 70 mm film in its original size (c)

evaluated the films of both sizes and studied the reports When there was disagreement between the two readers the films were re read Radiologist A now viewed the film sets previously read by radiologist B and vice versa All those 70 mm and full size films concerning which there was some disagreement were discussed by all three radiologists and a conclusion was reached

Technical data and equipment Examinations were performed with Philips radiographic and fluoroscopic tilt table Diagnost 60 and 9 image intensifier with a transistorized Plumbikon television chain A Philips 70 mm spot film camera was attached to the optical system of the image intensifier The feed cassette of this camera has a capacity of a 30 meter standard 70 mm film — enabling more than 400 exposures to be made The capacity of the take up cassette is approximately 45 frames the take up magazine can be removed and replaced in a lighted room Each exposed 70 mm frame is automatically numbered There is an exposure counter both on the camera and in the control room The F/5 camera lens has a focal length of 300 mm and is prefocused to infinity Exposures are released with a hand switch

Non perforated Kodak Rayoscope film was used and processed in a Kodak Xomat in ordinary roentgen developer at 29 C for two and a half minutes



Fig 6 Small ulcer on lesser curvature of the stomach 70 mm film without magnification technique The depth of the lesion was measured 1 mm on the full size film Full size film (a) enlarged 70 mm film (b) and 70 mm film in its original size (c)

and supine Patients in poor general condition or with profuse melaena were examined only recumbent An effort was made to record the same information on both the conventional and the 70 mm films As far as possible, films of both sizes were exposed in immediate sequence, with the patient in the same position, with same amount of contrast medium in the stomach or duodenal bulb, and the same compression applied

The fluoroscopic findings were available to the two senior radiologists and full size films were read immediately by one of them If necessary, supplementary fluoroscopic examination was carried out and additional films were obtained in order to augment the information The results of the readings were immediately reported, typed and signed

The 70 mm films were usually read the next day by the second senior radiologist, who was unaware of the results of the conventional study Both senior radiologists frequently interchanged their duties, in approximately equal number of examinations of both sizes were surveyed by each reader but during a short period of the time one of them was replaced by a third experienced radiologist The radiologist who did the fluoroscopy (the present author)



Fig 9 Case 5 (see Table) D sagreement in primary reading A 2 mm deep ulcer on the lesser curvature of the stomach isibl om both films though not reported in the primary read ng of the con ent onal films The 70 mm films were obtained without the enlargement technique

Results

Eleven of the 320 film sets could not be compared and were excluded from the study There was agreement in the readings of conventional and 70 mm films in 291 of the remaining 309 cases Some disagreement was evident in 18 cases as will be seen from the following tabular enumeration

Type of hanges	Ag eement	Disagreement	Total
He n a h atus esophag	81	—	81
Gastr r sect on	15	—	15
Muc al ch nges	16	4	20
Gast i ulcer or c cat ation	48	6	54
Duoden l ulcer or c cat tion	56	8	64
V r o s oesophageal	3	—	3
Cance of the stomach or c d	2	—	2
Internal b l ary fistula	2	—	2
Total pathologic find ng	223	18	241
N rmal findings	88	—	88
Full total	311	18	309

Readings with disagreement The 18 cases in which there was divergence of opinion were re viewed The differences in 7 of the readings involved changes

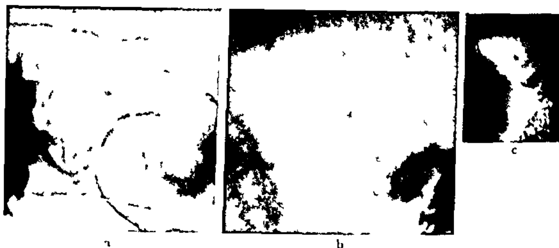


Fig 8 Small ulcer in the posterior wall of the duodenal bulb 70 mm film without magnification technique Full size film (a) enlarged 70 mm film (b) 70 mm film in its original size (c)

Conventional roentgenograms were obtained on Gevaert Curix film and developed in the Xomat under the same conditions as the 70 mm films

A 0 3 focus tube was employed for the 70 mm exposures and a 1 2 mm focus tube for conventional radiography Full size films were exposed at 125 kV, 1 to 30 mAs, and the 70 mm films at 1/5 to 1/10 of this exposure In slender patients, in whom the mucosal pattern was to be examined, or when strong compression was applied, the kilovoltage had to be reduced to 110 kV No phototimer was used A 3 mm Al filter and a 30 line per cm 1 7 grid were included

The geometric enlargement technique (magnification factor approximately 1 8) was applied in about 75 % of the cases (Figs 2 to 5) The 70 mm exposures were initially made without a grid (Figs 4 and 5) The quality of spot films of the stomach or the duodenal bulb was excellent but scattered radiation was excessive when a general view of the stomach was recorded

When working with the magnification technique, the application of compression was difficult, except in the prone position Furthermore, it was rather a time consuming procedure to make the 70 mm exposures with and the conventional roentgenograms without geometric magnification For this reason, and for testing the picture quality, 70 mm films were obtained in 75 patients under the same geometric conditions as for conventional films The diagnostic value of the 70 mm films without enlargement did not differ appreciably from the enlargement films (Figs 6 to 9) All the 70 mm films were viewed with the naked eye

Table (*cont*)

Repeat reading		Conference conclusion
Full size films	70-mm films	
No ulcer	No ulcer	No ulcer
No ulcer	No ulcer	No ulcer
No ulcer	No ulcer	No ulcer
No ulcer	No ulcer	No ulcer
Ulcus ventriculi	Ulcus ventriculi	Ulcus ventriculi
One ulcer	One ulcer	One ulcer
One ulcer	One ulcer	One ulcer
Cicatrisation	Cicatrisation	Cicatrisation
Ulcus ventriculi	Ulcus ventriculi ulcus duodeni	Ulcus ventriculi no duodenal ulcer
Ulcus ventriculi	Ulcus ventriculi	Ulcus ventriculi
Deformity	Deformity	Deformity no ulcer
Ulcus duodeni	Ulcus duodeni	Ulcus duodeni
Deformity ulcer healed	Deformity no ulcer demonstrated	Deformity small residual ulcer or cicatrisation
Ulcus duodeni	Ulcus duodeni	Ulcus duodeni
Ulcus duodeni	Ulcus duodeni	Ulcus duodeni
Ulcus duodeni	Ulcus duodeni	Ulcus duodeni
Ulcus duodeni	Ulcus duodeni	Ulcus duodeni
Deformity	Deformity	Deformity

Discussion

As indicated on p 362 there was agreement in all the 88 normal studies (28 % of cases) In the remaining 221 examinations 241 pathologic findings were demonstrated The frequence of hiatal hernias (81 cases or 26 % of cases examined) should not be considered unusual In each case an effort was made to demonstrate a hernia

There was agreement on three cases of oesophageal varicosis two cases of internal biliary fistula and two of carcinoma of the cardia The rather rare

Table

Presentation of readings in relation to the disagreement in primary reading

Type of changes Case number	Primary reading Full size films	 70 mm films
A *Mucosal thickening mistakenly interpreted as an ulcer*		
1	Ulcus pylori*	No ulcer
2	No ulcer	?Ulcus pylori ** incomplete
3	No ulcer	?Ulcus duodeni**
4	No ulcer	?Ulcus ventriculi**
B *Gastric ulcer*		
5 (Fig 9)	No ulcer*	Ulcus ventriculi
6	Two ulcers*	One ulcer
7	Two ulcers*	One ulcer
8	Cicatrisation	Cicatrisation technically inadequate**
9	Ulcus ventriculi ulcus duodeni*	Incomplete changes** in canalis ventriculi
10	No ulcer*	Ulcus ventriculi
C *Duodenal ulcer and postulcerous deformity*		
11	Deformity	?Ulcus duodeni**
12	Deformity*	Ulcus duodeni
13	Deformity small residual ulcer	Deformity ulcer healed
14	Ulcus duodeni	?Ulcus duodeni**
15	?Ulcus high mucosa**	Ulcus duodeni
16	Ulcus duodeni	Deformity incomplete**
17	Ulcus duodeni	Ulcus duodeni (?two ulcers**)
18	Deformity	Deformity ?ulcus duodeni**
* Diagnostic error	7	—
** Diagnosis doubtful		
Incompleteness	1	10

considered to be a gastric or duodenal ulcer by one of the readers and post ulcerous cicatrisation or high mucosal folds by the other In the other cases the interpreters had expressed some doubt regarding the diagnosis or had proposed a supplementary study

Disagreement occurred primarily in the group representing ulcers or post ulcerous changes A more detailed presentation of these readings is shown in an extensive Table, pp 364—365 Four cases with thickening of the mucosal folds are included since the presence of an ulcer was considered probable

An incorrect diagnosis was actually made in seven readings of full size films (1 3 % of all readings) In four cases a non existing ulcer was diagnosed and on three occasions an ulcer was missed No incorrect diagnosis was made in the primary reading of the 70 mm films however these were read under less stressed conditions The second radiologist did not at the repeat reading commit the error made in the primary reading of conventional films In one case the same reader incorrectly diagnosed a duodenal ulcer in his primary reading of full size films and repeated it in reviewing the 70 mm study, which was the only error made as regards the 70 mm films A conclusion could be made at the repeat reading in cases considered doubtful at the first reading

The higher number of mistakes in the readings of the conventional films was not the result of poor film quality it is likely that these changes were overlooked by the reader burdened with other routine work The value of repeat and dual readings which is a normal practice in our department, must be emphasized (see also ETTER et coll 1960)

Conclusions

The present comparative investigation indicates that morphologic details may be demonstrated in 70 mm films with the same accuracy as in roentgenograms of conventional size in the examination of the gastroduodenal tract It may therefore be possible to replace full size films with 70 mm spot films The advantages of 70 mm filming compared with conventional radiography are reduction in examination time less need for assistance during the examination reduction in the radiation dose and decreased film costs and filing space

SUMMARY

A comparative study of the gastroduodenal tract of 309 patients more than a third with ulceration by means of conventional roentgenography and 70-mm spot filming in connection with image intensification revealed that small lesions could be recorded as accurately by this method as with conventional full size films

ZUSAMMENFASSUNG

An einem Material von 309 Patienten von denen mehr als ein Drittel Magengeschwüre hatten wurden die Resultate der gewöhnlichen Röntgenuntersuchung mit den Ergebnissen verglichen die sich bei Benutzung von Bildverstärkern und 70 mm Film ergaben Die letztere Methode erwies sich ebenso gut für die Darstellung von kleinen Geschwüren wie die erste Methode

occurrence of malignant growth in this series is explained by the fact that with a few exceptions the patients examined were out-patients referred for ulcers.

As might be expected, there was disagreement in cases of gastric ulcer, duodenal ulcer or cicatrisation. The total number of sets of films demonstrating ulceration was 118 (38 % of cases examined, or approximately 50 % of all pathologic findings). The size of the ulcer varied between 1 and over 20 mm, measured on conventional films. One of the smallest ulcers is depicted in Fig. 6. Because of the disagreement in interpretation in 18 cases of ulcers, possible ulcers and hypertrophy of mucosal folds, all films of this group were reviewed. The percentage of revised cases cannot be considered high: 6 % of all examinations, 8 % of pathologic findings and 13 % of cases with ulceration or mucosal changes.

Minimal and moderate mucosal changes were disregarded. Duodenal diverticula were not classified as pathologic findings in this study.

The final review indicated that in all 18 cases the pathologic changes were equally well demonstrated in 70 mm films as in full size roentgenograms. The disagreement in readings was due to difference in the interpretation of changes observed, or a matter of opinion regarding the completeness of the examination.

Divergent interpretations of roentgenograms are not uncommon. For example, ETTER et coll. (1960), in their comparative study of the conventional method and cinefluorography of the gastroduodenal tract, recorded disagreement in 48 sets of films out of 116, i.e. approximately in 40 %, in spite of repeat readings, agreement on 12 sets could not be reached.

Disagreement in interpretation due to variations in film quality and reader experience may obviously occur. An effort was made in the present study to obtain exposures with equal and adequate picture quality. As much information as possible had to be demonstrated with a minimum number of exposures. Since conventional films were read immediately after the fluoroscopic examination, it was possible to obtain further 'takes' if the film quality was unsatisfactory or the films failed to demonstrate suspected changes clearly. The 70 mm films were processed later on the day of examination or on the following day so that a technical mishap could not be corrected. This was the reason why in 10 cases the reader of the 70 mm films hesitated to make a definite diagnosis, or requested a supplementary study.

The radiologist reading full size films always had earlier reports and roentgenograms available for comparison. The 70 mm films were usually read without comparison with previous studies.

A significant difference in experience of the readers could be ruled out, the ratio of their diagnostic errors in the primary reading of the full size films being 2 : 2 : 3. A final agreement was easily reached in all the 18 cases reviewed.

FROM THE ROENTGEN DEPARTMENT (DIRECTOR O SANDSTROM), THE CENTRAL HOSPITAL ESKILSTUNA SWEDEN

ROENTGENOLOGIC DETERMINATION OF LIVER VOLUME

Simplified method of calculation

by

L. WALK

The author has earlier published a paper in this journal (WALK 1961) on the roentgenologic determination of the liver volume The experience gained with the method applied as a routine in 530 cases has enabled the calculation of the volume to be simplified in that the step of separately correcting the three liver diameters has been eliminated by including a factor in the index and multiplying instead of dividing the product of the three diameters with the index The simplified method which will be described in this paper is similar to the method of determining the heart volume as generally applied in Sweden

The calculation is based on the assumption that the roentgenograms are obtained at a focus film distance of 120 cm The positioning during exposure as well as the method of measurement of the three liver diameters (A B and C) in the roentgenograms are the same as described in the previous paper

Presented at the XIth International Congress of Radiology Rome 1965 Submitted for publication 9 November 1965

RÉSUMÉ

L auteur a comparé l examen gastro duodénal de 309 malades dont plus d un tiers présentant une ulcération fait par la radiographie classique et sur film de 70 mm avec intensificateur d image Il conclut que les petites lésions sont aussi nettement visibles sur ces films que sur les films ordinaires en vraie grandeur

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ZUSAMMENFASSUNG

Die Berechnung des Lebervolumens ist zu Zwecken der laufenden klinischen Arbeit vereinfacht worden

RÉSUMÉ

L auteur décrit une simplification du calcul du volume du foie qui permet de l utiliser dans le travail courant

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Table

Indices to be used in children in calculations of the liver volume

Age of patient	Liver configuration			
	Round border	Normal border	Thin border	Thin border extreme cases
1 year	0.242	0.217	0.204	0.191
2—3 yrs	0.227	0.204	0.191	0.179
4—6 yrs	0.215	0.193	0.181	0.170
7—11 yrs	0.204	0.183	0.172	0.161
12—17 yrs	0.197	0.177	0.166	0.156

The diameters as measured in the roentgenograms are directly used for the calculation and their correction to true size, as described in the earlier paper, is thus no longer necessary. The following formula is used:

A B C index = liver volume

The size of the index, which now includes a factor to compensate for apparent enlargement due to projection, depends on the actual liver configuration, i.e.

Blunt thick border 0.19
Normal configuration 0.17
Thin flat border (average) 0.16
Thin flat border (extreme cases) 0.15

The method has been found to be less time consuming and errors are minimized. Liver volume per square meter of the body surface is clinically more informative than the total volume of the organ. A liver of up to 850 ml per m^2 body surface is normal, 800 to 900 ml/m^2 corresponds to a borderline case, and more than 900 ml/m^2 is definitely pathologic.

The index in children, as given in the Table, differs from that in adults, the difference being caused by the factor for compensation of the enlargement due to projection, which, as stated above, has been included in the index. This factor varies in relation to the age of the child.

As for adults, roentgenography of children is performed on a Bucky table.

SUMMARY

A simplification of the method of calculation of the liver volume to make it applicable to routine work is described.

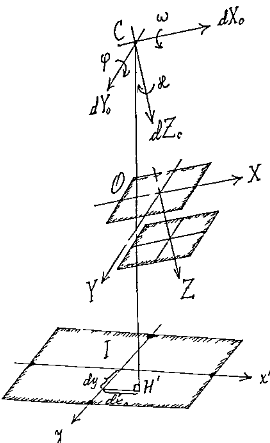


Fig 1 Definition of coordinates and rotations C — centre of perspective and focus with coordinates X Y Z which with corrections become dX dY dZ H — principal point CH — principal distance O — object or test device which defines the coordinate system X Y Z I — image with the coordinate system x y defined by frame marks

The roentgenographic system The system consists of roentgen tube image intensifier and a motion picture camera The roentgen tube is a Philips Rotalix with a rotating anode of about 0.3 mm × 0.3 mm focal size The image intensifier has an orifice diameter of 5 A screen which is made to fluoresce by the roentgen rays is in contact with a photocathode The electronic image is intensified by 25 kV and reduced in linear scale about 9 times The recording part of the apparatus is an Arriflex 35 mm motion picture camera with two Xenon lenses 1:2/75 mm and 1:1.5/55 mm

Definitions and basic formulas The roentgen picture is assumed to be a central projection with the perspective centre in the roentgen focus the latter is assumed to be a point and the image to be a plane The geometrical properties

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INTERIOR ORIENTATION OF A CINEROENTGENOGRAPHIC SYSTEM

by

K. TORLEGÅRD and I. WICTORIN

The image intensifier may be used in combination with a roentgen tube and a motion picture camera or television system for studying and registering such movements as the masticatory actions and the movements of the temporo mandibular joint. The skin dose of a registration will also be much lower when an image intensifier is used than when a full mouth examination is performed in the conventional manner.

When motion picture recordings have to be measured for determination of geometrical quantities (position, distances and angles), the whole or part of the interior and exterior orientations of the image creating system must be known. These questions have been dealt with by HALLERT (1958), HOLLENDER (1964), WICTORIN (1964), and KAASILA (1964), who all refer to the grid method used by HALLERT (1954).

A new method of determining the interior and exterior orientations will now be described. A three dimensional test device with well defined points, in known positions, was designed; the image coordinates of these points in the picture were measured and the orientation was computed.

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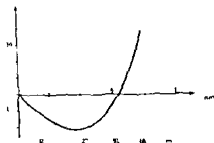


Fig 3 Radial distortion (d) and standard errors of unit weight (s) of the entire roentgenographic system

Using the notations in Fig 1 and the sequence of rotation ω, φ, κ the following general relation between the coordinates of the object and the image are obtained

$$x = x + c\,\frac{(X-X)\cos\varphi\cos\kappa+(Y-Y)(\sin\omega\sin\varphi\cos\kappa+\cos\omega\sin\kappa)-(Z-Z)(\sin\omega\sin\kappa-\cos\omega\sin\varphi\cos\kappa)}{-(X-X)\sin\varphi+(Y-Y)\sin\omega\cos\varphi+(Z-Z)\cos\omega\cos\varphi} \quad (1)$$

$$y = y - c\,\frac{-(X-X)\cos\varphi\sin\kappa+(Y-Y)(\cos\omega\cos\kappa-\sin\omega\sin\varphi\sin\kappa)-(Z-Z)(\cos\omega\sin\varphi\sin\kappa-\sin\omega\cos\kappa)}{-(X-X)\sin\varphi+(Y-Y)\sin\omega\cos\varphi+(Z-Z)\cos\omega\cos\varphi}$$

(see also HALLERT OTTOSSON 1959) (2)

If formulas (1) and (2) are expanded as a Taylor series from $\omega=0$, $\varphi=0$ and $\kappa=0$ the following formulas are obtained in the first approximation

$$\begin{aligned} dx &= dx + \frac{X-X}{Z-Z}\,dc - \frac{c}{Z-Z}\,dX + c\,\frac{X-X}{(Z-Z)}\,dZ - \\ &- c\,\frac{(X-X)(Y-Y)}{(Z-Z)}\,d\omega - c\left\{1+\frac{(X-X)}{(Z-Z)}\right\}d\varphi + c\,\frac{Y-Y}{Z-Z}\,d\kappa \end{aligned} \quad (3)$$

$$\begin{aligned} dy &= dy + \frac{Y-Y}{Z-Z}\,dc - \frac{c}{Z-Z}\,dY + c\,\frac{Y-Y}{(Z-Z_0)}\,dZ - \\ &- \left\{1+\frac{(Y-Y)}{(Z-Z)}\right\}d\omega + c\,\frac{(X-X)(Y-Y)}{(Z-Z)}\,d\varphi - c\,\frac{X-X}{Z-Z}\,d\kappa \end{aligned} \quad (4)$$

where dx and dy are the discrepancies between the measured image coordinates and the corresponding computed values using approximate data on the orientation Because of redundant observations an adjustment using the method of least squares is performed and corrections can be given to the approximate values of the orientation If the corrections are large iteration is advisable To obtain a solution of the system of equations the points of the object have to be distributed in three dimensions

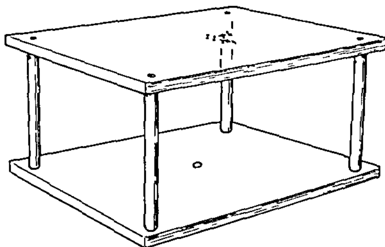


Fig. 2. The test device with measuring points orientated in circles.

of the picture are determined, first by the position of the focus in relation to the picture, which is the interior orientation, and secondly by the position of the object in relation to the picture, which is the exterior orientation.

The interior orientation may be defined as follows. The perpendicular from the perspective centre to the image plane is constructed. The foot of the perpendicular is the principal point and the length of the perpendicular is the principal distance. These are the elements of interior orientation which can be expressed with three coordinates of the focus given in a coordinate system defined by frame marks in the picture.

The exterior orientation may be defined by six elements, three of which give the position in space (coordinates) of the object and the other three (angles) the rotation in space of the object in the coordinate system defined by the frame marks (Fig. 1).

There are other possibilities of defining the interior and exterior orientations. Distortion and accuracy of the image coordinates are usually included in the interior orientation. The exterior orientation then gives the position and rotation of the picture in a coordinate system defined by the object. In Fig. 1, the object (the test device) defines the coordinate system (XYZ) in which the focus (perspective centre) has the position ($X_0 Y_0 Z_0$) which in the following computations will get the correction ($dX_0 dY_0 dZ_0$). The perpendicular from focus to image plane is CH, and it may be rotated through angles $d\omega$ and $d\varphi$ from the directions given by the XYZ system. Moreover, the xy system which gives the image coordinates may be rotated $d\kappa$ from the XY axes. The $d\omega$, $d\varphi$, and $d\kappa$ and dX_0, dY_0 and dZ_0 are corrections to be determined in the computations.

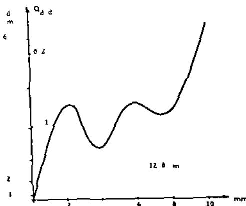


Fig 5 The standard error of the determination of the radial distortion (s_d) of the motion picture camera

(Fig 2) Lead discs 0 15 mm thick were glued on to the plates and holes, 0 5 mm in diameter, were drilled in the lead discs to define the point of the test device The position of the centre of each of these holes was determined in a three dimensional orthogonal coordinate system The lower plate had eight points and a ring of lead in the centre The upper plate had 79 points forming a pattern of concentric circles The coordinates of the points in the two plates were determined separately in a Wild StK 824 stereo comparator To get the points of the two plates in the same coordinate system the mounting of the test device was made in a SIP comparator in which measurements that related the coordinates of one plate to the coordinates of the other plate were made The distance between the plates was determined by using measuring gauges and standard gauge blocks The accuracy of the coordinates in terms of standard errors was for the upper plate $S_{X\ Y}=2\ 7\ \mu m$ for the lower plate $S_{X\ Y}=32\ \mu m$ and for the distance between the plates $Z-Z$ $S_{Z-Z}=$ 17 μm

Recording procedure To make it possible to separate the effect of the motion picture camera and the image intensifier two recordings were made with (1) the whole roentgenographic system and (2) the motion picture camera alone

1 The test device was fixed in front of the image intensifier to produce a symmetrical picture in the intensifier The roentgen tube was located near the perpendicular from the centre of the intensifier at a distance of about 1 15 m A series of exposures was made

2 The motion picture camera was separated from the system and used to photograph a grid etched on glass The distance between the lines of the grid was 1 101 mm and the grid coordinates had a standard error of 0 002 mm

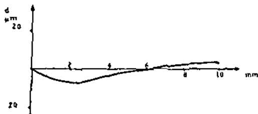


Fig. 4. Radial distortion (dr) of the motion picture camera. r denotes the radius of the measuring circle

If the object is a plane nearly parallel to the picture, formulas (1) and (2) are expanded in Taylor series, assuming $X_0 = 0$, $Y_0 = 0$, $Z_0 = 0$, $c = c$, $\omega = 0$, $\varphi = 0$, $\varkappa = 0$, $x_0 = 0$, and $y_0 = 0$. The radial distortion, dr, is assumed to be a fifth degree polynom with the radius as the independent variable

$$dr = a_1 r + a_2 r^2 + a_3 r^3 + a_4 r^4 + a_5 r^5 \tag{5}$$

But $dc/c = dr/r$ and, in the first approximation, the following observation equations are obtained

$$dx = x\,(a_1 + a_2 r + a_3 r^2 + a_4 r^3 + a_5 r^4) + dx - \frac{xy}{c}\,d\omega + \left(1 + \frac{x^2}{c^2}\right) c\,d\varphi + y\,d\varkappa \tag{6}$$

$$dy = y\,(a_1 + a_2 r + a_3 r^2 + a_4 r^3 + a_5 r^4) + dy - \left(1 + \frac{y^2}{c^2}\right) c\,d\omega + \frac{xy}{c}\,d\varphi - x\,d\varkappa \tag{7}$$

$$\text{where } x = \frac{X}{Z}c,\quad y = \frac{Y}{Z}c \text{ from (1) and (2)}$$

$r = \sqrt{x^2 + y^2}$ and dx and dy are the discrepancies between measured and given values.

In order to test the hypothesis that the radial distortion is zero, the significance of parameters a_2, a_3, a_4 and a_5 is investigated, a_1 is completely correlated to the distance from the object and thus excluded from the test. Two adjustments are made, one including and the other excluding these parameters. In the first case the sum of squared residuals is $\Sigma\, v_1^2$, and in the second case it is $\Sigma\, v_2^2$. The number of observations is n, the total number of parameters is k and the number of parameters under test is m.

Therefore,

$$F = \frac{n-k}{m} \times \frac{\Sigma v_2^2 - \Sigma v_1^2}{\Sigma v_1^2} \tag{8}$$

where F follows an F distribution with $(m,\ n-k)$ degrees of freedom if the hypothesis is true. The critical region of the zero hypothesis is the $100\,\alpha$ % largest values of F (α = significance level). (See KENDALL–STUART 1961.)

Test device. The test device consists of two plates of plexiglas (150 mm × 206 mm) connected to each other by four tubes also made of plexiglas

Scale factors The image intensifier had a scale factor of 1 9 110 the motion picture camera had a scale factor of 1 0 713, and the entire system had a scale factor of 1 6 494

Conclusions

HOLLENDER (1964) showed that the roentgen bundle of rays recorded on glass plates is free from distortion and had a standard error of unit weight of about 20 μm under his experimental conditions In our investigation no distortion of the motion picture camera could be observed and so it seems justifiable to state that radial distortion of the actual recording system is con centrated to the image intensifier For radii larger than 6 mm in the scale of the negative the image intensifier also introduces most of the irregular errors The geometric image quality is comparatively good in the central part of the picture The radial distortion cannot be seen in ordinary occular viewing but when measurements aiming at geometric determinations of high accuracy have to be made on the images it is necessary to introduce corrections for the radial distortion

SUMMARY

A roentgenographic system consisting of roentgen tube image intensifier and motion picture camera was tested partly by means of the grid method for determining distortion and accuracy and partly by a new method by means of which also the principal point and the principal distance were obtained The theoretical basic formulas and mathematical relations between the geometric elements ar described

ZUSAMMENFASSUNG

Eine Ronteenapparatur bestehend aus Rontgentubus Bildverstarker und Cinekamera wurde teilweise mit der Gittermethode auf Verzerrung und Genauigkeit und teilweise mittels einer neuen Methode die den Hauptpunkt und die Bildkonstante ermittelt untersucht Die grundsatzlichen theoretischen Gesetze und die mathematischen Beziehungen zwischen den geometr schen Faktoren werden b schrieben

RESUME

Un équipement radiograph que comportant un tube un intensificateur d image et une cir ecamé a a été testé d une part par la méthode de la grille pour juger la d storsion et la p écision et d aut e part une nouvelle méthode qui donne aussi le point principal et la distance p ncipale Les auteurs indiquent les formules théoriques de base et les relations mathe matiques entre les élements géométriques

The film was developed in a May & Baker Roentgen Developer 340 for 8 minutes at 20° C and rinsed for 30 seconds. It was fixed for 10 minutes, and finally washed for 30 minutes.

Results

1. Radial distortion and accuracy were determined according to the grid method given by HALLERT (1954). The results appear in Fig. 3. The standard error of unit weight, s_0, indicates that the irregular errors increase with the radius.

2. *Formulas (6) and (7) were used to obtain the observation equations.* Applying the method of least squares, estimates of the unknowns, the standard error of unit weight and the matrix of weight and correlation numbers were obtained. The standard error of unit weight was 12.8 µm. The radial distortion curve and its accuracy are shown in Figs. 4 and 5. The accuracy has been determined by applying the general law of error propagation to *formula (5)*. When testing the hypothesis that the radial distortion is zero, the value of F in formula (8) was calculated to 0.828, which means that no distortion could be determined in the optical system of the motion picture camera.

Principal point and principal distance. The radial distortion of the whole roentgenographic system was determined, and if the image coordinates are corrected for this regular error, the image intensifier and the motion picture camera change only the scale of the image. The perspective properties of the picture of the object are then given by the roentgen bundle of rays, the interior orientation of which is determined. Formulas (3) and (4) for points in the two planes of the test device give, after solution, the following values of the interior elements of the roentgen bundle of rays and their standard errors:

Principal point

$x_0 = +\ 12.24$ mm $s_x = 5.19$ mm

$y_0 = +\ 2.88$ mm $s_y = 3.61$ mm

Principal distance

c = 1294.50 mm $s_c = 7.63$ mm

Standard error of unit weight $s_0 = 0.073$ mm

These values refer to the picture which is formed by the roentgen bundle of rays on the receiving screen of the image intensifier.

The focus of the roentgen tube is the centre of the perspective. The accuracy (s_0) is in accordance with the determination shown in Fig. 3 because the actual radii were about 8 mm in the scale of the picture where $s_0 = 0.068$ mm.

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XERORADIOGRAPHIE — EIN VERFAHREN ZUR BILDERZEUGUNG IN DER RÖNTGENDIAGNOSTIK

von

FRIEDRICH KOSSEL

Die Xeroradiographie ist ein Verfahren zur Herstellung von Röntgenaufnahmen, bei denen die Ladung an der Oberfläche einer isolierenden Platte durch die Einwirkung der Strahlung eine dem Strahlungsrelief entsprechende Verteilung erhält. Das so erzeugte Ladungsbild kann nach der Exposition durch Aufstäuben eines elektrisch aufgeladenen Pulvers sichtbar gemacht werden. Die Herstellung von gleichmäßigen Schichten aus isolierenden Materialien, deren Isolationswiderstand während der Bestrahlung so weit erniedrigt wird, daß eine Änderung der Ladungsverteilung entstehen kann, hat in den letzten Jahren erhebliche Fortschritte gemacht. Auch die Aufladetechnik und das trockene Entwicklungsverfahren (nach dem die Xerographie ihren Namen hat) mit sehr feinkörnigem Kunststoffpulver (sogenanntem Toner) haben einen Entwicklungsstand erreicht, durch den die Xerographie in verschiedenen Bereichen der Lichtphotographie, z. B. in der Reproduktionstechnik, eine ernstzunehmende Konkurrenz zur Photographie mit Silberhalogeniden geworden ist (CLAUS 1963, DESSAUER et coll. 1955).

Bei der Redaktion am 20. September 1965 eingegangen

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WICTORIN L Bone resorption in cases with complete upper denture Acta radiol (1964) Suppl No 228

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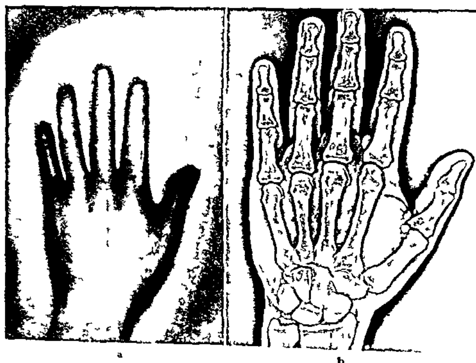


Abb 2 a) Erste xeroradiographische Aufnahme einer Hand b) Xeroradiographie einer Hand Aufnahmedaten 60 kV 30 mAs F 2 mm Al 1 m Fokus Platten Abstand

arbeitendes Verfahren angegeben worden dessen Empfindlichkeit nur durch das Quantenrauschen begrenzt ist Diese Ergebnisse ermutigen dazu die wesentlichen Unterschiede darzustellen die zwischen der elektrostatischen Bildentstehung und den Aufnahmen mit Röntgenfilm bestehen

In der Entwicklung der Xerographie ist die Tendenz zu beobachten Ergebnisse zu erreichen die insbesondere auch in der Wiedergabe von Halbtönen mit den üblichen photographischen Aufnahmeverfahren vergleichbar sind Die Eigenheiten der elektrostatischen Bildentstehung eröffnen jedoch Möglichkeiten der radiographischen Darstellung die mit Röntgenfilmen überhaupt nicht oder nur äußerst schwierig erreichbar sind Unter diesem Gesichtspunkt ist die Xeroradiographie zum gegenwärtigen Zeitpunkt noch kein Ersatz des bewährten Röntgenfilms, möglicherweise aber eine brauchbare Ergänzung

Das xeroradiographische Aufnahme und Entwicklungsverfahren ist in Abb 1 schematisch dargestellt Die Selenplatte ist in einer durch einen Schie

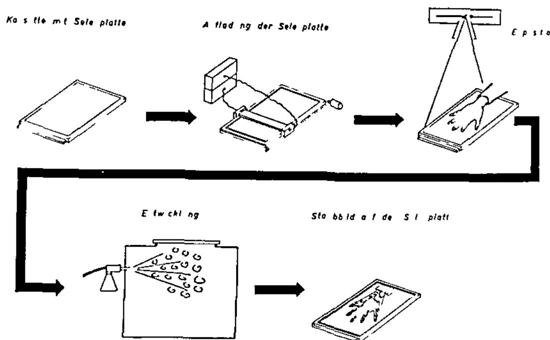
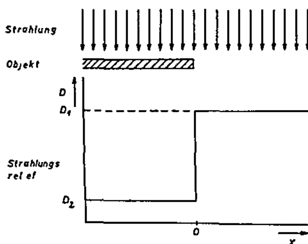


Abb. 1. Ablauf des xeroradiographischen Verfahrens

Bei der in der Praxis bereits bewährten Anwendung in der Reproduktionstechnik, z. B. zur Herstellung von Bürokopien, wird als Ladungsträger eine glasige amorphe Selenmodifikation von dunkelrotbrauner Färbung benutzt, die im Vakuum in einer 30 bis 40 μm dicken Schicht auf eine Aluminium-Unterlage aufgedampft wird. Der spezifische Isolationswiderstand ist im Dunkeln größer als 10^{15} Ω cm (siehe Gmelins Handbuch) und erniedrigt sich je nach der Intensität der einfallenden Strahlung um 2 bis 3 Zehnerpotenzen.

Die Anwendung in der Röntgentechnik war bisher wegen des relativ hohen Dosisbedarfs der Materialprüfung vorbehalten. Aus dem medizinischen Bereich liegen nur wenige Versuche vor (FARMER et coll. 1963, GOULD et coll. 1960, OLIPHANT 1955, ROACH & HILLEBOE 1955). Wir hatten Gelegenheit, mit wesentlich empfindlicheren ebenfalls für die Materialprüfung entwickelten Platten, bei denen die Selenschicht eine Dicke von 60 μm hatte, einige Versuche zu machen. Durch die erhöhte Empfindlichkeit ist eine erneute Überprüfung des Verfahrens auf seine Brauchbarkeit für die Röntgendiagnostik interessant geworden. Die Entwicklung in den letzten Jahren zeigt, daß eine weitere Steigerung der Empfindlichkeit von der Überwindung einiger technologischer, nicht aber prinzipieller Schwierigkeiten abhängt. Von REISS (1965) ist kürzlich ein allerdings anderes mit einer Gasverstärkung





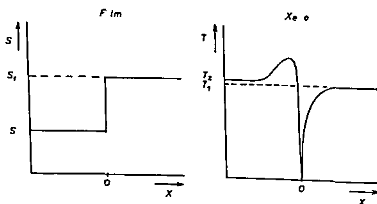


Abb 4 B ldentstehung schemat sch

durch Anlosen mit Trichlorathylendampf oder Anschmelzen durch leichte Erhitzung haltbar gemacht werden

Die Selenplatten sind im ungeladenen Zustand beliebig lange haltbar und mussen weder vor Licht noch Strahlung geschutzt werden Jede Platte kann mehrere tausend Male benutzt werden Das Entwicklungsverfahren beansprucht nicht mehr als 10 Sekunden so daß die Aufnahme bereits kurz



Abb 3 Oberschenkelaufnahme
Aufnahmedaten 80 kV 60 mA Fi 2 mm Al
1 m Fokus Platten Abstand

ber lichtdicht verschlossenen Kassette untergebracht Die von uns benutzten Kassetten hatten Abmessungen von 44 × 30 cm Die Fläche der Selenschicht betrug 35 × 23 cm In einem lichtdichten Kasten wird die Kassette geoffnet und mit einer Koronaentladung auf ca 800 V elektrostatisch aufgeladen Diese Ladung bleibt im Dunkeln mehrere Stunden unverandert Die Kassette wird im geschlossenen Zustand der Aufladevorrichtung entnommen und ist fertig fur die Exposition Nach der Exposition wird die Kassette in einem zweiten lichtdichten Kasten mit der Selenschicht nach unten angeordnet, der Schieber geoffnet und die Ladungsverteilung durch mit Preßluft eingeblasenen Staub sichtbar gemacht Danach kann das Staubbild auf der Selenplatte sofort betrachtet werden Wir haben ein hellblaues Kunststoffpulver verwendet, das sich beim Zerstauben elektrisch aufladet und bevorzugt an den Stellen hoher Ladungsdichte niederschlagt Das hellblaue Pulver ist auf der dunkelrotbraunen Oberflache der Selenplatte gut erkennbar Zur dauerhaften Fixierung kann das Bild von der Selenplatte abphotographiert werden oder man uberdeckt es mit weißem Papier und ladet die Platte erneut auf Dadurch wird das Pulver auf das Papier ubertragen und kann dort

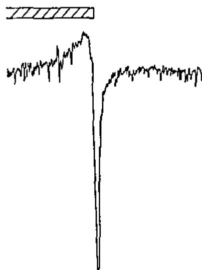


Abb. 6. Originale Photometerkurve entlang einer halbabgedeckten Selenplatte nach der Entwicklung

man auf die Details, die im originären Staubbild auf der Selenplatte zu erkennen sind, nicht verzichten will, muß man das Bild abphotographieren. Immerhin ist das Bild nach kurzer Zeit wenigstens einer Betrachtung zugänglich. Für eine dauerhafte Dokumentation bleibt zunächst nur der Umweg über die Photographie.

Zur Erzeugung von Bildern, die noch ohne Informationsverlust der Betrachtung zugänglich sind, benötigt man eine Dosis von 30 mR an der Selenplatte. Um im direkten Kontakt xeroradiographische Bilder auf das Papier zu übertragen, ist eine Dosis von mindestens 80 mR erforderlich. Die Expositionsdauer kann ohne merkbare Beeinträchtigung der Bildqualität bis zu einem Faktor 4 verlängert werden. Mit den von uns benutzten, noch nicht im Handel befindlichen Spezialplatten wird eine Empfindlichkeit erreicht, die mit dem folienlosen Film verglichen werden kann. Bei dünneren Platten ist der Dosisbedarf um einen Faktor 3 bis 5 höher. Im Bereich von etwa 40 bis 120 kV ändert sich die Empfindlichkeit um weniger als 10 %.

Das xeroradiographische Bild

Die erste xeroradiographische Aufnahme einer Hand (Abb. 2a) hat RIGHI (1907) im Jahre 1903 hergestellt. Er verwendet als Isolator zur Speicherung der Ladung eine Ebonit-Platte und als strahlungsabhängigen Isolationswiderstand eine darüber befindliche dünne Luftschicht. Im Prinzip ist es dasselbe Verfahren, mit dem REISS (1965) eine besonders hohe Empfindlich-

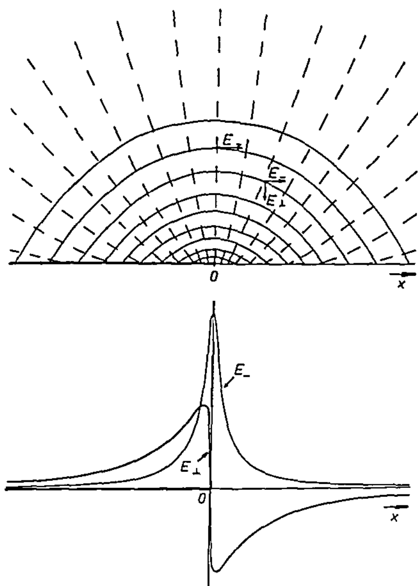


Abb. 5. Feldlinienverlauf dicht vor der Oberfläche der Selenplatte, links durch Objekt abgedeckt; *ausgezogen* Feldlinien, *gestrichelt* Äquipotentiallinien. Darunter Verlauf der Feldstärkekomponenten $E_=$ parallel zur Selenplatte, $E_\perp$ senkrecht dazu.

nach der Exposition betrachtet werden kann. Die Verarbeitung bei Tageslicht und die kurze Entwicklungszeit sind sicher auch für verschiedene medizinische Anwendungen, z. B. für Aufnahmen bei Operationen, von Vorteil.

Ein technologisch noch nicht zufriedenstellend gelöstes Problem ist die Übertragung des Staubbildes von der Selenplatte auf Papier, die nach unseren Erfahrungen mit einer erheblichen Qualitätseinbuße verbunden ist. Wenn

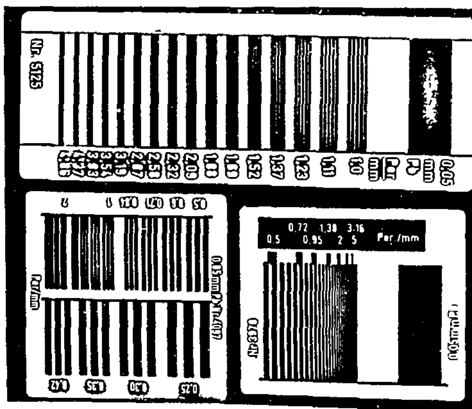


Abb 8 Strichraster ufnahme Einfallsdosis an der Selenplatte 122 mR

Unterhautfettgewebe Gefaße und Muskelstrange erkennbar Auch die Fingernagel bei der Aufnahme der Hand sind deutlich abgebildet

Kontrastunterschiede sind wie schon in Abb 2a erkennbar durch eine schwarze Grenzlinie voneinander getrennt die bei erheblichen Dosisunterschieden wie z B zwischen der durch *Weichteil* geschwachten Strahlung und der ungeschwachten Strahlung eine erhebliche Breite hat Bei solchen erheblichen Kontrastunterschieden konnen in dem Grenzgebiet feine Details verloren gehen

Weichteilstrukturen werden im Bereich des Knochen nicht dargestellt Das bedeutet daß kleine Dosisdifferenzen bei hoher Gesamtdosis im Strahlungsrelief zur Abbildung kommen daß aber kleine Dosisdifferenzen bei kleiner Gesamtdosis im Strahlungsrelief wie z B im Knochen bevorzugt dargestellt werden

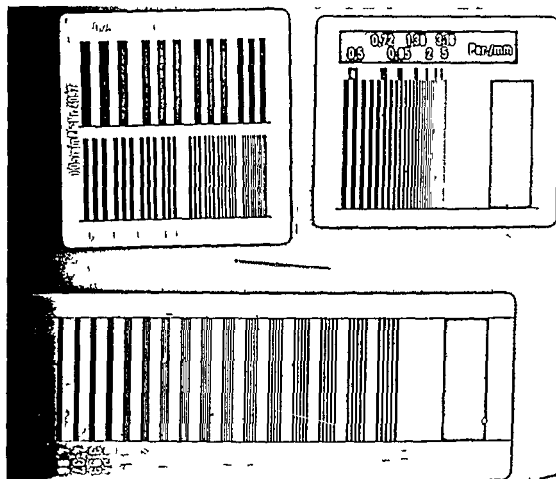


Abb 7 Strichrasteraufnahme Einfallsdosis an der Selenplatte 15 mR

keit erzielt hat Zum Bestauben wurde eine Mischung aus Schwefel und Mennige benutzt (Daß man auf diese Weise elektrische Ladungen sichtbar machen kann, ist lange vor Entdeckung der Photographie und der Rontgenstrahlen von LICHTENBERG (1777) gezeigt worden) Die Aufnahme ist in der Originalarbeit farbig, innerhalb des Umrisses der Hand rot, außen gelb Auf diesem Bild sind die Knochen gerade noch andeutungsweise zu erkennen 1937 wurde das Verfahren von CARLSON (1938, 1939) erneut entdeckt und in den USA patentiert Im Vergleich zu Abb 2a zeigt Abb 2b den gegenwartigen Stand der Technik

Aus Abb 2b und teilweise besser noch aus Abb 3 konnen bereits einige typische Kennzeichen xeroradiographischer Aufnahmen abgelesen werden

Es kommt ein großer Objektumfang zur Darstellung Neben allen Einzelheiten der Knochenstruktur sind auch Weichteilstrukturen, wie z B das

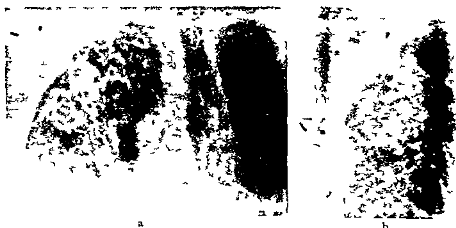


Abb. 10. Lungenaufnahme mit Co-Strahlung. Fokus-Platten-Abstand 72 cm. Dosis an Selenplatte 5 R. a) Übersicht, b) Feldeinstellung

Eine Erklärung für den Verlauf der Tonung im xeroradiographischen Bild liefert Abb. 5. Unter der Einwirkung der Strahlung sinkt der Isolationswiderstand der nicht vom Objekt abgedeckten Hälfte der Selenplatte stärker ab als in dem anderen Teil. Dadurch befinden sich nach Abschluß der Exposition bei nunmehr wieder gleichmäßig hohem Isolationswiderstand auf der rechten Seite weniger Ladungen als auf der linken Seite, so daß sich unmittelbar über der Selenschicht ein Kraftlinienfeld bogenförmig ausbilden kann (NEUGEBAUER 1964). Bei der Bestaubung folgen die elektrisch geladenen Staubteilchen diesen Kraftlinien. Wenn man die Feldstärke, die auf die Staubteilchen einwirkt, in zwei Komponenten zerlegt, eine davon parallel zur Platte und eine davon senkrecht zur Platte, so sieht man, daß an der Grenze des Objektes nur eine Komponente vorhanden ist, die die Staubteilchen von diesem Gebiet wegtreibt. Der Verlauf der beiden Feldstärkekomponenten ist unter dem Feldlinienbild dargestellt. Die senkrechte Komponente steigt langsam an, durchläuft in der Nähe der Objektgrenze den Nullpunkt, um dann von negativen Werten her wieder abzunehmen. Die parallele Feldstärkekomponente hat an der Objektgrenze ihr Maximum. Unabhängig davon, wie groß die Ladungsdifferenz zwischen den beiden Hälften der Selenplatte ist, entsteht in der Mitte immer ein Bereich, der von Staubteilchen nicht erreicht werden kann. Dies erklärt, weshalb wir in xeroradiographischen Bildern für jeden, auch für kleine Kontraste eine schwarze Konturierung finden. Die Tonung hat einen Verlauf, der dem der senkrechten Feldstärkekomponente ähnelt. Abb. 6 zeigt die Original-Photometer-Kurve einer bestaubten xeroradiographischen Platte, die während der Exposition zur Hälfte mit 2 mm

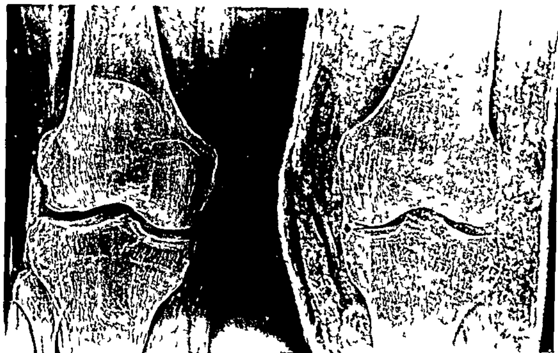


Abb. 9. Kniegelenke rechts in Gips. Aufnahmedaten: 80 kV, 200 mAs, Fi. 2 mm Al, 1 m Fokus-Platten-Abstand

Die Tönung im Bereich, der von Direktstrahlung getroffen wird, im Weichteilbereich, z. B. bei der Hand, und im Mittelbereich der Knochen ist nicht sehr unterschiedlich. Die Abbildung hat gegenüber einer Röntgenaufnahme einen kleinen Schwärzungsumfang.

Das xeroradiographische Bild unterscheidet sich wesentlich von der Aufnahme auf Röntgenfilm, so daß ein Vergleich nicht ohne weiteres möglich ist. In Abb. 4 ist die unterschiedliche Bildentstehung schematisch dargestellt. Das von oben kommende Strahlenbündel soll durch ein Objekt zur Hälfte stark geschwächt werden. Dann ergibt sich im Strahlungsrelief ein Dosisunterschied zwischen der ungeschwächten Strahlung mit der Dosis D_1 und der Dosis D hinter dem Objekt. Dieser wird auf dem Film in zwei verschiedene Schwärzungen S_1 und S_2 umgesetzt, die an der Objektgrenze, bedingt durch Unschärfe, Korngröße usw. einen mehr oder weniger steilen Übergang haben. Im xeroradiographischen Bild steigt die Tönung zur Grenze des Objektes hin zunächst an, um an der Grenze auf Null abzusinken und dann langsam mit zunehmendem Abstand wieder anzusteigen, bis praktisch die gleiche Tönung erreicht ist. Mit steigendem Dosisunterschied im Strahlungsrelief ist dieser letzte Anstieg langsamer, so daß die gestrichelte Linie erst in einem größeren Abstand von der Objektgrenze erreicht wird.

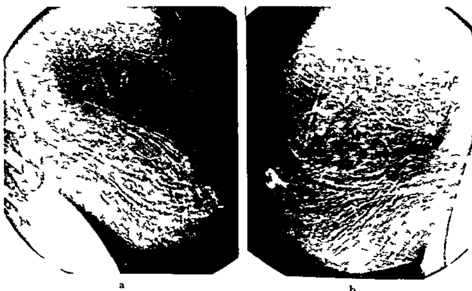


Abb. 12. Mammographie. Aufnahmedaten: 60 kV, 100 mAs, Fi 2 mm Al, 87 cm Fokus-Platten-Abstand. a) Linke Mamma, b) Rechte Mamma

konturenreich darzustellen, grenzen die Einsatzmöglichkeiten gegenüber dem Röntgenfilm ab. Der mit dem folienlosen Film vergleichbare Dosisbedarf erscheint vertretbar, wenn dadurch zusätzliche Informationen gewonnen werden können.

Als Beispiel für die Darstellung eines erheblichen Objektumfanges sind in Abb. 9 zwei Kniegelenke in einer Aufnahme dargestellt, wobei die Knochenstrukturen innerhalb des Gipsverbandes zur Abbildung kommen und gleichzeitig am gesunden Knie eine Weichteilzeichnung erkennbar ist. Auch für Lokalisationsaufnahmen in der ultraharten Strahlentherapie direkt mit ^{60}Co-Strahlung eröffnen sich interessante Möglichkeiten. Abb. 10a und 10b zeigen eine Lungenaufnahme und die dazugehörige Feldeinstellung. Der Dosisbedarf ist ähnlich wie bei Röntgenfilmen (Kuttig & Frischbier 1961), um etwa einen Faktor 30 höher als in der Röntgendiagnostik. Die Kontraste reichen für eine Einstellungsorientierung aus. Die Abbildung wird wahrscheinlich im wesentlichen durch die von der ^{60}Co-Strahlung erzeugten Sekundärelektronen bewirkt, die möglicherweise auch für die körnige Struktur verantwortlich sind. Abb. 11 stellt ein mit ^{60}Co-Strahlung aufgenommenes Becken mit luftgefüllter Blase dar. Dieses Bild zeigt den Gewinn an Kontrast gegenüber der Verwendung von Röntgenfilmen noch deutlicher.



Abb. 11. Beckenaufnahme mit luftgefüllter Blase mit ^{60}Co-Strahlung. Fokus-Platten-Abstand 72 cm. Dosis an Selenplatte 5 R.

Blei abgedeckt war und mit einer Einfallsdosis von 48 mR an der Selenplatte exponiert wurde. Mit solchen Feldlinienbildern lassen sich die im xeroradiographischen Bild beobachtbaren Effekte beschreiben.

Das Auflösungsvermögen wird weniger durch die Korngröße des Entwicklerstaubes, sondern durch die gegenseitige Beeinflussung benachbarter Kontraste begrenzt, wie in Abb. 7 und Abb. 8 zu erkennen ist. Bei schwacher Exposition werden Auflösungen bis zu 4 Per./mm (Abb. 7) erreicht. Mit zunehmender Belichtung sinkt das Auflösungsvermögen, wobei auffällt, daß es bei den einzelnen Testobjekten unterschiedlich groß ist, je nachdem wie stark der Einfluß der Umgebung auf das Rasterbild ist.

Aus diesen beiden Bildern geht auch hervor, daß die Abbildung mit zunehmender Belichtung nicht mehr maßstabgerecht erfolgt. So sind bei der stärker belichteten Aufnahme die Stege schmaler als die Schlitze, obwohl beide im Objekt gleich breit sind. Feldlinienbetrachtungen, ähnlich wie für Abb. 5 ergeben, daß die Stege zunächst kontrastreicher werden, bevor sie verschwinden. Auch das trägt dazu bei, daß in der xeroradiographischen Wiedergabe kleine Details zwar nicht maßstabgerecht, jedoch mit hohem Kontrast abgebildet werden.

Anwendungsbeispiele

Der erhebliche Objektumfang, der auf xeroradiographischen Aufnahmen zur Darstellung kommt und die Möglichkeit, auch kleine Kontraste noch

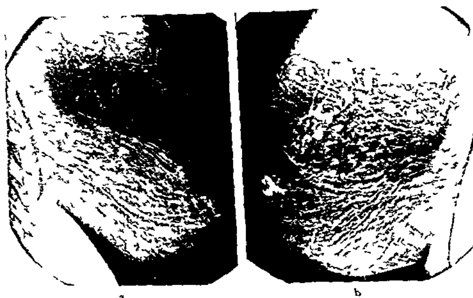


Abb 12 Mammographie Aufnahmedaten 60 kV 100 mAs Fi 2 mm Al 87 cm Fokus Platten Abstand a) Linke Mamma b) Rechte Mamma

konturenreich darzustellen grenzen die Einsatzmoglichkeiten gegenuber dem Rontgenfilm ab Der mit dem folienlosen Film vergleichbare Dosis bedarf erscheint vertretbar wenn dadurch zusatzliche Informationen gewonnen werden konnen

Als Beispiel fur die Darstellung eines erheblichen Objektumfanges sind in Abb 9 zwei Kniegelenke in einer Aufnahme dargestellt, wobei die Knochen strukturen innerhalb des Gipsverbandes zur Abbildung kommen und gleich zeitig am gesunden Knie eine Weichteilzeichnung erkennbar ist Auch fur Lokalisationsaufnahmen in der ultraharten Strahlentherapie direkt mit ^{60}Co-Strahlung eroffnen sich interessante Moglichkeiten Abb 10a und 10b zeigen eine Lungenaufnahme und die dazugehorige Feldeinstellung Der Dosisbedarf ist ahnlich wie bei Rontgenfilmen (KUTTIG & FRISCHBIER 1961) um etwa einen Faktor 30 hoher als in der Rontgendiagnostik Die Kontraste reichen fur eine Einstellungsorientierung aus Die Abbildung wird wahr scheinlich im wesentlichen durch die von der ^{60}Co Strahlung erzeugten Sekundarelektronen bewirkt die moglicherweise auch fur die kornige Struktur verantwortlich sind Abb 11 stellt ein mit ^{60}Co Strahlung aufgenommenes Becken mit luftgefullter Blase dar Dieses Bild zeigt den Gewinn an Kontrast gegenuber der Verwendung von Rontgenfilmen noch deutlicher

Die ausgeprägte Darstellung geringer Kontraste macht die Xerographie möglicherweise auch für Weichteildarstellungen geeignet. In Abb. 12 werden zwei an einer Person mit relativ harter Strahlung aufgenommene Mammographien gezeigt. Der Tumor zeichnet sich im rechten Bild neben einer Fülle anderer Details deutlich ab.

Es ist uns bekannt, daß an den technologischen Problemen der Xeroradiographie intensiv gearbeitet wird. Die Entwicklung hat einen Stand erreicht, der nicht als Ersatz, wohl aber als Ergänzung des Röntgenfilmes das Interesse des Radiologen beanspruchen darf.

ZUSAMMENFASSUNG

Die Erzeugung elektrostatischer Ladungsbilder und ihre Sichtbarmachung durch Aufstäuben elektrisch geladener Staubteilchen ist zur röntgenographischen Darstellung (Xeroradiographie) in der Medizin brauchbar. Der Dosisbedarf ist gegenwärtig nicht größer als beim folienlosen Film. Die Besonderheiten der elektrostatischen Bildgebung, vor allem der grosse Objektumfang, der zur Darstellung kommt, und die kontrastreiche Wiedergabe geringer Unterschiede des Strahlungsreliefs sind geeignet, Anwendungen zu suchen, bei denen der Röntgenfilm bisher nur unzureichende Ergebnisse lieferte.

SUMMARY

Electrostatic charge patterns and their presentation as an image made visible by sprayed on charged particles are useful for radiographic procedures (xeroradiography) in medical radiology. The required dosage is at present not higher than that applied in ordinary non-screen radiography. The characteristics of an electrostatic charge pattern, in particular the great number of discernible details and the good rendering of small differences in local contrast should make xeroradiography particularly suited in cases where ordinary roentgen films give unsatisfactory results.

RÉSUMÉ

La production d'images de charges électrostatiques rendues visibles par saupoudrage de particules électriquement chargées est utilisable en radiologie médicale (xeroradiographie). La dose nécessaire n'est pas supérieure actuellement à celle qui est utilisée pour les films sans écran ordinaires. Les caractéristiques de l'image électrostatique, en particulier le grand nombre de détails discernables, le haut contraste local comparé à un faible contraste d'ensemble font que la xéroradiographie est particulièrement indiquée dans les cas où les radiographies ordinaires ont donné des résultats insuffisants.

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Book Reviews

DIAGNOSTIC NEURORADIOLOGY By Juan M Taveras and Ernest H Wood 1960 pages and 722 illustrations Williams & Wilkins Co Baltimore 1964 Price 32 50 dollars

Neuroradiology has progressed rapidly during the past twenty years and is now an important specialty recognized by those working in neurology neurosurgery and allied fields as indispensable both in clinical practice as in research work It is therefore surprising that no textbook has hithertoo been available in the English language especially when it is remembered that Lindgren's work in German (Rontgenologie in Handbuch der Neurochirurgie) now considered a classic was published more than ten years ago Probably one of the reasons for this deficiency has been that hitherto no competent specialists have been interested in the subject — at least in the U S The present book is another good example of how rapidly advances can be made when enthusiastic well trained radiologists lead the research in their own special fields American neuroradiology has recently made great strides and it is obvious from this book that it now occupies a leading position

The book is divided into four parts dealing with the skull intracranial pneumography angiography and diseases of the spinal cord The different sections are in the reviewer s opinion proportionately well balanced give essential information and avoid speculation The bibliography includes about 500 titles and thus covers most of the important original publications on neuroradiology The work has considerable didactic merits and contains a large number of well selected roentgenograms of high quality and new diagrams (The reviewer could have wished that the drawings had been more correct at least as regards the essential features The third ventricle for instance is always drawn as if it were deformed) The text is concise and arranged in a manner to make it easy to follow Preliminary knowledge on the subject is not necessary and the book can thus be used by beginners at the same time it contains much of interest to specialists

It is often said that the fate of all textbooks is to be out of date on the day of publication and naturally certain details in the present book warrant this quip A drawing showing the arteries of the basal ganglia constitutes a good example in its present form it will tend to preserve the generally held though incorrect view on the anatomy of these vessels — one that the reviewer has also contributed towards spreading A more exhaustive and in some measure different treatment would have been desirable in one or two sections For example the author stated that the deformity of the ventricular system referred to as angular shift should not be of localizing value in severe subfalcial herniation does not accord with the reviewer s experience In the description of intracranial deformities the absence of any general opinion on the mechanical factors underlying the displacement and their effect on different structures is sometimes noticeable This is particularly so in the chapter on angiography where little is said about the conclusions that can be drawn from seeing both the arterial and the venous deformity at the same time The choice of illustrations for this section has also suffered from the omission

This is a good book but perhaps it is too much to say with the St Louis Post Dispatch of October 9th 1964 that it represents the definitive work in the field There is surely work left for others who are fascinated by the hope that much remains undone in neuroradiology

Torgny Greitz

PNEUMOENCEPHALOGRAPHY AND CEREBRAL ANGIOGRAPHY By B S Epstein 349 pages and 219 figures Year Book Medical Publishers Chicago 1966 Price 20 dollars

This monograph has been so arranged that the encephalographic and angiographic changes in most intracranial pathologic conditions are considered together The contents of the book are grouped under four main headings (1) normal pneumoencephalograms and angiograms (2) congenital malformations (3) vascular malformations and intracranial hemorrhage and (4) brain tumours The author has consequently been forced to include many conditions under somewhat unorthodox headings For example atrophic lesions are discussed under congenital malformations and vascular occlusions including embolism and thrombosis under vascular malformation This is a little disturbing especially for students

An extensive list of references is included but most of the text seems to be founded upon the author s own experience

The main interest is focused upon the neuroradiologic diagnosis of cerebral tumours and only scant attention is paid to modern roentgenologic procedures in the examination of ischemic cerebral conditions It is stated in the chapter dealing with cerebral hemorrhage that the lenticulo-striate arteries are difficult to identify The reviewer has however seldom had trouble in recognizing these in adequate angiograms their displacement medially is a valuable sign of intracerebral hemorrhage The technique of examination of arterial aneurysms is incompletely described and the importance of oblique views and the circle of Willis receive only a few words

Many errors appear in the chapter dealing with normal pneumoencephalograms especially in the part dealing with the anatomy of the cisterns The descriptions of the normal appearances of the cisterns and of their anatomy are rather complicated and are not easy to understand they are also somewhat contradictory The author appears to be unfamiliar with the appearances of the fourth ventricle in pneumoencephalography as shown by the legends to several of the illustrations

The encephalographic and angiographic changes in cerebral tumours are dealt with in detail The subtraction method is however not mentioned although a modern angiographic examination of the cerebral vessels is hardly complete without it It is especially valuable in diagnosing meningiomas and demonstrating their blood supply from branches of the meningeal arteries The author states that filling of the external carotid artery is of great help in the diagnosis of meningiomas The reviewer believes that the external carotid artery should certainly always be examined selectively when a meningioma is likely to be present

The book contains many illustrations although some of them especially in the angiographic examinations are not of the best quality Possibly this impression is mainly due to the small size Each chapter is furnished with an extensive list of references The work forms an extensive review of the modern aspects of encephalography and cerebral angiography and as such will be of great value to the experienced neuroradiologist

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Practical procedures in diagnostic radiology By H M Saxon and Basil Strickland 275 pages 60 illustrations and 10 tables H K Lewis London 1964 Price 50 shillings

This book is intended partly for the trainee or postgraduate and partly for the ordinary radiologist to provide an extension of the range of procedures in which he is competent

It must be stressed that a great difference exists between experience in performing an examination and making a good diagnosis An example may be mentioned the technique of arthrography is easy to acquire but the diagnostic analysis of the roentgenograms needs knowledge that can be obtained only by practical experience under a good teacher The indications for a complicated examination also necessitate critical assessment

A chapter on emergencies in the roentgen department comes early in the book Various investigations are then discussed Examinations of the genito urinary and biliary tracts as well as the vascular sy tem here take pride of place Today few radiologists would agree with the objections mentioned to the compression technique in urography a method that has in general been used for at least twenty years Retrograde urethrography is not discus sed Micturition urethrograms alone never afford adequate information about the urethra Gas cystography or double-contrast techniques as complements to ordinary cystography which are useful procedures receive no attention The use of an elastic tube to connect the syringe and the cannula in dacrocystography should have been adopted Fluoroscopy as an aid to bronchography is generally considered to be important and ought to have been recom mended

With regard to the preparation of the patient the advisability of recommending a single substance for example Dulcolax is certainly questionable Developments in the pharma ceutical field rapidly lead to the introduction of new preparations

An appendix contains certain valuable facts on e g catheters needles contrast media The book might have been improved if some of the recommendations given and the pro cedures described had been brought up to date

Ove Mattsson

Radiology of the digestive system By K Lumsden and S C Truelove 540 pages 359 figures 2 tables Blackwell Scientific Publications Oxford 1965 Price 6 £

The rather special purpose of this book is indicated by the authors in the preface Our aim in this book is to present the essentials of diagnostic radiology of the digestive system in a form su table for physicians and surgeons This means that it is not written for radiologists but for clinicians It is a rad ologic companion to Diseases of the Digestive System by Truelove & Reynell from the same publishers and must be regarded more as guide for specialists who co-operate with the radiologist Criticism is consequently difficult The book is well written and lavishly illustrated with no less than about 360 good illustrations *mostly representing characteristic findings* without special problems Such a survey must obv ously be of considerable general value and the work fulfills its purpose It can also be recommended to those just beginning their training in rad ology

J Frimann Dahl

CALCIFICATIONS OF THE HEART By J H Shapiro H G Jacobson Berta M Rubenstein M H Poppel John B Schwedel and J Jorgens Charles C Thomas Springfield Illinois 1964 Price 12 50 dollars

This work which has been produced for radiologists cardiologists and surgeons is a joint effort by well known radiologists most of them at the Montefiore Hospital New York The clinical material available to the authors seems to have been immense

A large variety of calcifications are considered each type being presented in a separate chapter with a number of references The opinions of previous authors are summarized and thoroughly discussed The book is unique in that many of the cases have been verified with special roentgenograms prepared from autopsy specimens The educational approach is excellent and there is probably nothing left out and nothing that requires to be added as regards cardiac calcifications Intracardial and pericardial calcifications and those associated with the coronary vessels are all described and discussed The literary references are assembled for each chapter and subject which facilitates their use

The good layout makes the most of the material The logetronic method of contrast-levelling contributes to the transfer of all the available information to the block prints The logetronic reproductions are mostly well done none of them presenting the exaggerated effect that has sometimes been observed in similar work Brief historical introductions open up to each chapter The roentgen findings as well as the differential diagnosis are discussed in detail The authors series of cases has been well selected

The majority of the material consists of standard projections as a complement detailed roentgenograms obtained with well framed beams would have been of value Over penetrated films might sometimes also have been of help many of the films included are ordinary chest films and therefore underexposed in respect to intracardiac structures Exposure factors would have been of interest at least for some of the roentgenograms especially since widely different conditions exist today for chest roentgenography and no general standard has been accepted The kilovoltage in the case of calcifications ought of course to be kept rather low although there must be a compromise to avoid unsharpness produced by movement, for that reason it seems that facts about exposure conditions as well as data on grids should have been included by the authors

The cineradiographic demonstration of cardiac calcifications is discussed in a special chapter by J Jorgens The author states that for small objects such as calcifications small image intensifiers (5 inch) give the best results and that larger amplifiers tend to diminish the image This is an important observation and one with which many radiologists will agree The author has used 16 mm cinefilm but might have been impressed by what can be obtained with 35 mm film Exposure data are not given nor any details about camera speed and exposure conditions It should be stressed that pulsing may be the only adequate way of depicting small rapidly moving intracardiac calcareous deposits It is necessary to reduce the exposure time for each frame to the minimum No illustrations from the cineroentgenographic recordings are included

The author of this review has had the opportunity of visiting the Montefiero Hospital and study a number of the original films the reproductions seem to represent all that could be deduced from the excellent clinical material and the book will constitute a good addition to the library of every radiologist

Ove Mattsson

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RENAL ARTERY CHANGES IN HYPERTENSION

by

INGER BROLIN

Renal hypertension may be defined as high blood pressure caused by occlusive disease of the renal arteries which is potentially curable either by reconstructive arterial surgery or nephrectomy (MAXWELL & PROZAN 1962) Certain clinical facts suggest a renovascular cause e g its onset before 35 and after 55 years of age non familial hypertension of recent onset in any patient regardless of age with rapid progression into a malignant phase, and hypertension that develops or is exacerbated following unilateral pain in the flank or abdomen (POUTASSE 1959) The history may thus suggest that constriction of the main renal artery is responsible for the hypertension Although angiography can demonstrate and localize any vascular lesion this examination does not clarify the haemodynamic implications (OWEN 1959 AMPLATZ 1962 HOWARD & CONNOR 1962 MAXWELL 1962 DENNIS et coll 1963) Stenosis of renal arteries has been demonstrated in normotensive cases particularly in the higher age groups (BLACKMAN JR 1939 LISA et coll 1943 RICHARDSON 1943, BRETSCHGER 1951 SUTTON et coll 1961 EYLER et coll 1962 SCHWARTZ & WHITE 1964) Roentgenologically demonstrated stenosis in a hypertensive patient is consequently not necessarily the aetiologic factor

From Roentgen Department I (Director Prof S R Kjellberg) and Roentgen Department II (Director Docent I Wickbom) Sahlgrenska Sjukhuset Gothenburg Sweden
Submitted for publication 6 September 1965

LYMPHOGRAPHIE UND TUMORDIAGNOSTIK Von W A Fuchs 117 Seiten 100 Abb in 141 Einzeldarstellungen Springer Verlag Berlin 1965 Preis 38 DM

This book based on a series of 244 cases of malignant growths deals with the value of lymphography in tumour diagnosis The normal roentgenographic anatomy and pathologic changes in the lymph nodes are discussed following upon four chapters devoted to the examination technique contrast media, complications and contra indications

The author believes that it is seldom possible to make an early diagnosis of malignant diseases in the lymph nodes but cancer metastases may in many instances be demonstrated by lymphography before they have produced any clinical signs A differential diagnosis between primary malignant disease in the lymph nodes and metastases is possible only exceptionally Lymphography is greatly superior to all indirect roentgenographic methods for evaluating the retroperitoneal lymph nodes and thus forms a valuable asset in diagnostic radiology

The book gives a good review of our present knowledge in the field The illustrations on the whole are excellent

Erik Lindgren

DIE WIRBELSAULENLEIDEN UND IHRE DIFFERENTIALDIAGNOSE 4 erweiterte Auflage Von J E W Brocher 684 Seiten mit 511 Abbildungen in 1057 Einzeldarstellungen Georg Thieme Verlag Stuttgart 1966 Preis 166 DM

This is the fourth edition of this book The long chapter on tuberculous spondylitis and its differential diagnosis (124 pages) remains the same as in earlier editions The author s description of this disease is based on experiences from a time when tuberculosis was much commoner than it is today but because of its exhaustive nature it is still a valuable source of knowledge for the diagnosis of the rare instances of the disease that still occur and for those who are working with the tuberculosis problem in non European countries

Spondylarthritis ankylopoietica (pelvospondylitis ossificans) Scheuermann s disease and the constitutional forms of diseases are described in great detail and with many illustrations The chapter on malformations has been supplemented with a section on the changes in the occipitocervical region Detailed descriptions of spondylosis osteoporosis osteomalacia the sclerosing structural changes and the reticuloendothelial diseases are given in the second chapter The chapters on tumours and fractures have been enlarged New chapters take in the vertebral column as a whole and deal with incorrect posture and abnormal curvatures the determination of motility in different parts of the spine and the nature of regional pain are also discussed Finally there are sections on the differential diagnosis and the prognosis

This book is the work of one man and in consequence the chapters are harmoniously balanced As the illustrations derive mainly from the author s own practice he has been able to describe the clinical signs and present confirmations of the diagnoses The biography comprises 38 pages and the illustrations are excellent The book gives a complete presentation of roentgen diagnosis in diseases of the spine and the author deserves our gratitude for his solid comprehensive and instructive work

Folke Knutsson



Fig 2 Bilateral stenosis caused by periadventitial fibrosis a) In a 43 year-old man in whom at operation thick and tough connective tissue was found to surround both the renal arteries distally close to their origins b) In a 47 year-old man in whom the moderate bilateral stenosis was due to bands from the diaphragmatic crura

vessel wall but no obvious constriction of the lumen were not included A histologic diagnosis (F Knutson) was available in 39 operated and 5 autopsy cases A study was made in the first place of the angiographic features in these verified cases

The contrast medium was always injected into the abdominal aorta through a catheter introduced percutaneously into the femoral artery The examination was sometimes complemented by selective angiography To facilitate demonstration of the orifices without superimposition stereoscopic films were obtained with a biplane roll film or a cut film changer (Elema Schonander) at an exposure rate of 3 to 6 films/sec The injection of contrast medium was repeated if necessary after the patient had been rotated 45 to the right or left

Results

I Changes in the main trunk of the main renal artery and its bifurcation (verified cases)

Atherosclerotic stenosis (25 cases) Stenosis of this nature was due to atherosclerosis either of the abdominal aorta with constriction of the orifice of the renal artery to changes in the main trunk or to a combination of these two forms The constriction was caused by fibrous plaques and was generally accentuated by haemorrhage and calcification Thrombotic deposits were present on the atherosclerotic focus in seven cases

The stenoses had certain typical angiographic appearances (Fig 1) The position was often eccentric since the lesion was more marked in part

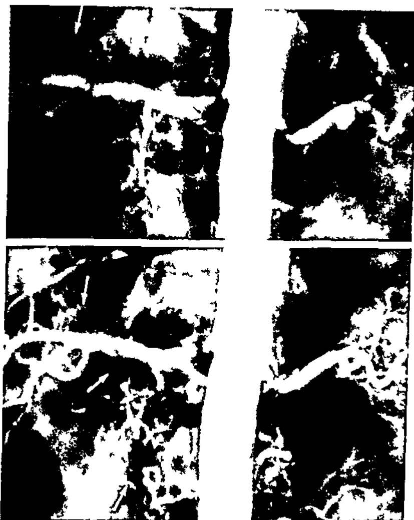


Fig 1 Bilateral atherosclerotic stenosis of the main renal artery Even in the early arterial phase (top view) tortuous collaterals (arrow) are visible on the right side Later (bottom view) the collateral circulation is seen to be abundant (arrows)

Stenosis may be due to local disease of the main renal artery or be a component of systemic vascular disease In the latter instance, the high blood pressure may be caused by the generally increased peripheral resistance

The author analyzed a series of cases of arterial hypertension examined between January 1st 1959 and June 30th 1964 in order to ascertain whether it is possible angiographically to distinguish between the causes of different types of stenosis The series comprising 91 men and 73 women, contains not only cases of stenosis but also cases with other pathologic changes in the main renal artery or its large branches Cases only with irregularities of the



Fig 4 Severe bilateral stenosis of the main renal artery in a 35-year old man Extensive mural lesions of the aorta Microscopical diagnosis arteritis of unknown origin

hyperplasia was situated more peripherally In two cases the large branches of the artery were also affected

Arteritis (one case) Solid fibrous strands were evident at operation around both main renal arteries and the aorta particularly at the level of the renal artery Microscopy disclosed severe arteritic lesions with degeneration of the media Adjacent to small areas of necrosis numerous cellular infiltrates contained giant cells the aetiology of which could not be established

Angiographically there was marked bilateral stenosis in the proximal parts of both main renal arteries (Fig 4) as well as confluent irregular mural changes in the aorta The changes were of the same character as seen in atherosclerosis

Intimal fold (one case) This was verified only at operation No microscopic examination was made since the vessel was not resected Roentgenography revealed a thin fold at a distance of about 1 cm peripheral to the orifice (Fig 5)

Aneurysm (one case) The main trunk was dilated into an aneurysm about 2 cm in diameter peripheral to which it was markedly stenosed In addition to this aneurysm angiography disclosed another one in the proximal part of each one of two wide lumbar arteries



Fig 3 Two cases of fibromuscular hyperplasia with multiple fold like stenoses in a 45 year old woman (a) and in a 47 year old man (b) The aneurysmal dilatations are more distinct in the latter

of the circumference of the vessel The contour was generally somewhat uneven and passed into an irregular arterial wall The stenosis was always situated at the orifice or in the proximal half of the main trunk The main trunk was occluded in the seven cases of thrombosis

Periadventitial fibrosis (8 cases) Fibrous tissue constricting the vessel externally was seen at operation in these cases In one of them, the tissue consisted of bands from the diaphragmatic crura, and microscopy revealed that it consisted of hyperplastic connective tissue

A funnel shaped, concentric constriction with smooth contours (Fig 2) was seen in most of the cases (in six) *In two, however, the stenosis had the same somewhat irregular contour as seen in atherosclerotic stenosis* The lesion *was situated at the orifice in one case but in the others it lay 0 5 to 1 cm farther* peripherally

Fibromuscular hyperplasia (4 cases) The pathologic process was located in the media, where hyperplasia particularly of the smooth muscle, alternating with disruption or absence of elastic fibres was observed The wall was thinner than normal in the latter areas and the vessel was sometimes dilated so that an aneurysm was suggested

The angiographic examination disclosed multiple fold like stenoses, in between them the artery was either of normal width or dilated (Fig 3) The orifice was not involved in any one of these cases but the fibromuscular



Fig 6 Infarction in the caudal pole The occluded branch of the renal artery is indicated by an arrow

Distribution of the changes (see Table 1) Almost two thirds of the material consisted of atherosclerotic stenosis 70 % of the men and 59 % of the women belonging to this group The men also predominated in the group of periadventitial fibrosis whereas all the cases of aneurysm were in women

Degree of stenosis The normal width of the artery cannot be measured in the presence of stenosis of the orifice with poststenotic dilatation When part of the main trunk is projected axially the poststenotic dilatation may be partly superimposed on the stenosis which makes it impossible to measure the diameter of the latter The reduction in the lumen was consequently not calculated but the classification was confined to slight or severe stenosis and occlusion

The atherosclerotic stenosis were slight in 58 % severe in 32 % and total in 10 % of the cases Occlusion and severe stenosis were more frequent on the left side (Fig 7) Since there were only 27 cases of non atherosclerotic stenosis (periadventitial fibrosis fibromuscular hyperplasia intimal fold and arteritis) the percentage figures are uncertain the corresponding figures are however 65 % 32 % and 3 % Occlusion was present in only one case



Fig 5 Intimal fold (arrows) in a 53 year old man (a) (angiographic finding verified at operation) and in a 50 year old woman (b) *A distinctly delimited fold* in the proximal part of the left main renal artery was visible at both these angiographic examinations

2 Changes in the large branches of the main renal artery (verified cases)

The pathologic changes were localized to one of the large branches in five cases, in two of these, the histologic diagnosis was atheromatosis, and in the other three it was embolism, fibromuscular hyperplasia and subintimal fibrosis, respectively

These five cases had the same angiographic appearance An area of the renal parenchyma was not filled during the nephrographic phase (Fig 6) In two cases, *the occluded branch could be localized by means of the position of the infarction* Since it is not possible roentgenologically to distinguish between peripheral vascular lesions of varying aetiology these have in the following been denoted collectively as infarction

3 Changes seen in the whole material

An attempt was made to establish the diagnosis in the remainder of the material from the angiographic features of the verified cases Because of their characteristic appearances, fibromuscular hyperplasia, intimal fold, aneurysm and infarction are easy to classify Also the atherosclerotic stenoses were in most of the cases *of typical appearance, however it was not possible* in ten cases (6 %) to establish whether the stenosis was of a fibrotic or atherosclerotic nature



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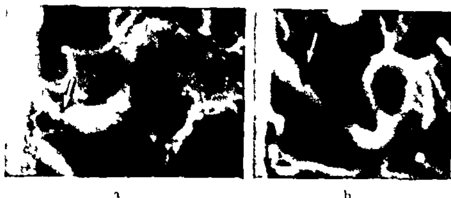


Fig. 5. Intimal fold (arrows) in a 53 year old man (a) (angiographic finding verified at operation) and in a 50 year old woman (b). A distinctly delimited fold in the proximal part of the left main renal artery was visible at both these angiographic examinations.

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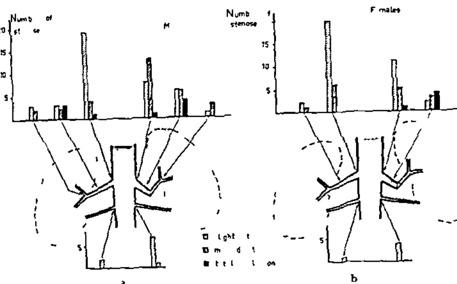


Fig 7 Schematic demonstration of the sites of the atherosclerotic stenoses in men (a) and in women (b)

Almost a third of the cases with atherosclerosis had bilateral stenosis In volvement of supplementary renal arteries was also evident The multiple locations are illustrated in Fig 13 which shows the appearances of the other renal arteries in stenosis of the right and left main trunks The contralateral main renal artery was more often stenosed than normal in width

The non atherosclerotic stenosis were bilateral to about the same extent (37 %) They were confined to the main renal artery

Collateral circulation In cases of occlusion or severe stenosis of the main renal artery the peripheral part of the vessel involved was supplied by collaterals from the suprarenal lumbar and/or ureteric arteries via capsular arteries (Fig 1) Collaterals were observed in 23 % of all the cases Their incidence in the various types of stenosis is recorded in Table 3 Little difference was present in this respect between atherosclerotic stenosis (26 %) and that of other origin (22 %) Collaterals occurred in the former more often on the left side than on the right (33 % and 9 % respectively)

In two cases of infarction collateral circulation via extrarenal arteries had developed in the same way as in stenosis of the main trunk In the third case anastomoses between small branches of the main renal artery — probably

Table 1

Distribution of the cases according to the diagnosis

	In men				In women				Total
	No.	Mean age yrs	Opera-tion	Au-topsy	No.	Mean age yrs	Opera-tion	Au-topsy	
Atherosclerotic stenosis	64	53.7	16	1	43	54.6	6	2	107
Periadventitial fibrosis	6	36.3	6		2	25.0	2		8
Fibromuscular hyper-plasia	4	44.0	2		6	45.2	1	1	10
Arteritis	1	35	1		—	—	—		1
Intimal fold	3	53.7	1		5	49.2	—		8
Aneurysm	—	—	—		7	49.7	1		7
Infarction	8	44.9	3		5	44.8	1	1	13
Unclassified	5	40.6	—		5	49.8	—		10
	91		29	1	73		11	4	164

Localization. The situation of the various types of stenosis is apparent from Figs. 7 and 8. All cases with stenosis of the orifice have been assigned to one group, irrespective of the peripheral extent of the lesion.

The orifice was involved in 69 % of the atherosclerotic stenosis (Fig. 7). The remainder were present chiefly in the proximal part of the main trunk, the distal part being involved in only 8 %. When the orifice was stenosed, atherosclerosis of the aortic wall was present, extending in most cases (61 %) into the main renal artery (Fig. 9). The non-atherosclerotic stenoses were situated chiefly in the distal part of the vessel (Fig. 8). The orifice was constricted in only one case.

The sites of the aneurysms are schematically shown in Fig. 10. In addition to the aneurysm previously described, a fusiform aneurysm was present in the main trunk, at a distance of 0.5 to 1 cm from the orifice. The other aneurysms were saccular and lay at the bifurcation (Fig. 11).

The locations of the infarctions are schematically indicated in Fig. 12. Although somewhat more common on the right side there was no apparent site of predilection for these infarctions.

Incidence of bilateral lesions. The respective distribution on right and left side, as well as the incidence of bilateral lesions, are recorded in Table 2. Fibromuscular hyperplasia, like infarction, was more common on the right side. Fibromuscular hyperplasia confined to the left renal artery was present in only one case.

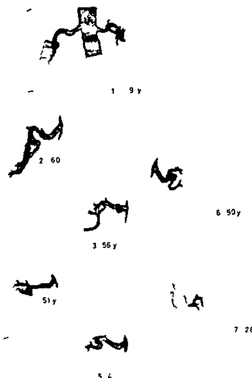


Fig 10 S tes of aneurysms Case 7 subjected to operat on had se ere stenos s of the main enal artery peripheral to the aneurysm No narrow ng of the lumen of the renal artery was e dent n the other cases Ca e 6 also had a renal cyst

to the renal pelvis and calyces — had become collaterals to peripheral parts of the occluded branch (Fig 14)

Aortic lesions Mural lesions of the aorta were studied at the same time as the stenoses of the renal arteries Occasional irregularities were denoted as slight atherosclerosis multiple mural changes as moderate atherosclerosis and confluent changes with constriction or aneurysmal dilatation of the aortic lumen as severe atherosclerosis

Involvement of the aorta was more common in cases of atherosclerotic stenosis than in those with stenosis of other origin It is evident from Fig 15 in which the various age groups are compared that this could not be ascribed only to the higher mean age in the former category of cases The cases of atherosclerotic stenosis include one with stenosis also in the proximal part of the superior mesenteric artery and eight with collateral circulation between

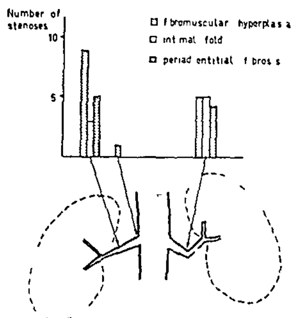


Fig 8 Schematic demonstration of the sites of the non atherosclerotic stenoses

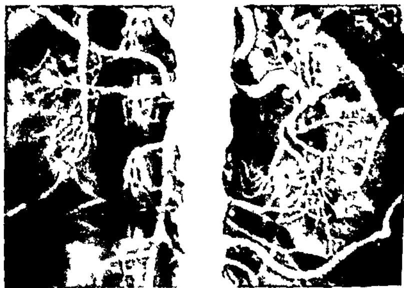


Fig 9 Extensive atherosclerotic changes in the aortic wall with narrowing of the orifice of both the main renal arteries the aortic changes extend into the renal artery

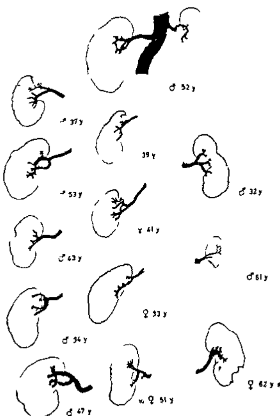


Fig 12 Sites of infarctions The filling defects are shaded and the occluded branch where it could be identified is marked with a cross

1964 PALUBINSKAS et coll 1964) Although atherosclerosis has predominated in these large series as in the present one the incidence figures have varied greatly in view of the series being selective

All authors have stressed the proximal location of the atherosclerotic stenoses as well as the fact that lesions are generally present in the abdominal aorta The incidence of bilateral involvement has ranged from 21 % (POUTASSE et coll) to 50 % (PALUBINSKAS et coll) Still higher figures were reported in an autopsy series (SCHWARTZ & WHITE) Thus in 55 to 64 % of cases with severe stenosis of one renal artery the contralateral artery was also stenosed The main renal artery on the side opposite to the stenosed one was normal in only 9 to 18 % of cases However, this series was small and derived chiefly from the higher age groups

Atherosclerosis of the abdominal aorta was present in practically every case of the present series as well Stenosis of the main renal artery was bilateral



a b

Fig. 11. Examples of aneurysms, saccular (a) and fusiform (b).

splanchnic vessels, indicative of proximal stenoses that could not be depicted at nephroangiography. No involvement of splanchnic vessels was observed in cases of non-atherosclerotic stenosis.

Operation results. A detailed account of the results of operation will be given in a later paper, and the present survey is consequently based only on clinical evaluation of the patients' postoperative condition (H. Kjellbo). The patients were divided into three groups, i.e. normotensive, improved and unchanged. The observation period was long enough to permit such an evaluation in 32 of the 40 operated cases (Table 4). Four patients died in connection with operation. It is evident that no difference existed between the results in cases of atherosclerotic and of non-atherosclerotic stenosis.

A comparison between cases with and without collateral circulation is presented in Table 5. Although the results seem to be slightly better in the presence of collaterals, the series is too small to permit any definite conclusions.

Discussion

Many cases of hypertension have been described following the demonstration by GOLDBLATT et coll. (1934) that it may be produced by a decreased blood supply to the kidneys. Series of more than 100 cases have not, however, been reported until in recent years (POUTASSE et coll. 1961, DE BAKEY et coll.

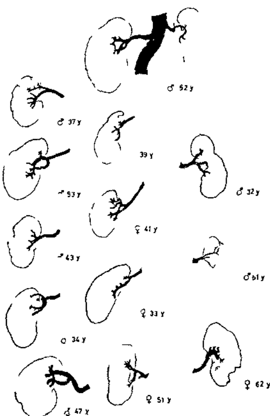


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Table 2

Distribution of the cases according to right sided, left sided and bilateral involvement

	Right sided	Left sided	Bilateral	
			No	
Atherosclerotic stenosis	34	39	34	31.8
Periadventitial fibrosis	2	2	4	50.0
Fibromuscular hyperplasia	5	1	4	40.0
Arteritis	—	—	1	
Intimal fold	3	4	1	12.5
Aneurysm	4	2	1	14.3
Infarction	9	3	1	7.7
Unclassified	8	2	—	
	65	53	46	

Table 3

Number of cases with collateral circulation

	Right sided	Left sided	Bilateral
Atherosclerotic stenosis	4	22	2
Periadventitial fibrosis	1	—	—
Fibromuscular hyperplasia	1	1	—
Arteritis	—	—	1
Intimal fold	2[1]	—	—
Aneurysm	—	1[2]	—
Infarction	3[1]	—	—
	11	24	3

[1] Left sided nephrectomy in one case
[2] Stenosis peripheral to the aneurysm

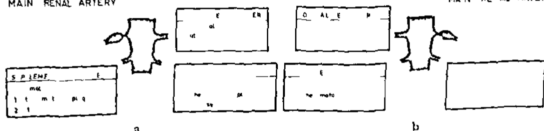


Fig 13 Schematic representation of the degree of changes in other renal arteries in the presence of stenosis of the right (a) and left (b) main branch



Fig 14 Collateral circulation in occlusion of a branch of the main renal artery The contrast medium was injected selectively into the renal artery a) Early arterial phase with occlusion of a branch (⟶) this branch had been filled with medium at an examination 3 years earlier b) Numerous small tortuous vessels particularly around the pelvis and cranial calyces are filled from other intrarenal branches c) Filling of capsular arteries (⊸) in caudal parts of the kidney the peripheral part of the occluded branch starts to be filled (↔) d) Further filling of the occluded branch the medium has disappeared from the other in

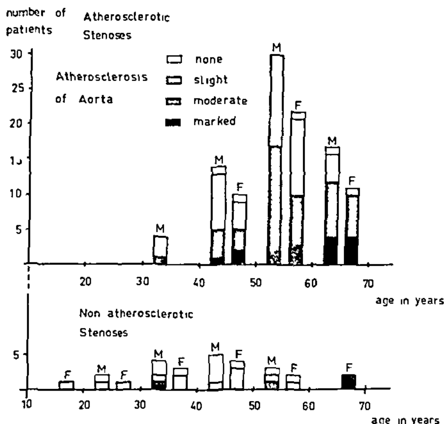


Fig. 15. Comparison between involvement of the aorta in atherosclerotic and non atherosclerotic stenosis

and a component of generalized atherosclerosis in almost a third of the cases. This implies that the stenosis may not have been responsible for hypertension. This possibility was pointed out as early as 1939 by OPPENHEIMER et coll., who found in autopsy cases that stenosis of the renal arteries was combined with generalized atherosclerosis, these authors expressed the view that the atherosclerotic lesions of the renal arteries were caused by hypertension rather than vice versa. On the other hand, accounts have been given of many cases which have become normotensive after resection of the renal arteries with atherosclerotic stenosis (CONNOR et coll. 1957, BROWN et coll. 1960, POUTASSE et coll., DE BAKEY et coll., PALUBINSKAS et coll.).

The difficulty is to determine what forms of stenosis are responsible for hypertension. It is also not yet fully established which factor (or factors) elicits formation of the *hypertensive substances producing renovascular* hypertension. The decreased blood flow to the renal parenchyma is of decisive importance. No single method of examination yet exists which ascertains with

Table 4

Results of operation in relation to the diagnosis

	Normotensive	Improved	Unchanged
Atherosclerotic stenosis	3	8	6
Periadventitial fibrosis	1	3	2
Fibromuscular hyperplasia	—	2	—
Arteritis	—	1	—
Intimal fold	—	1	—
Aneurysm	1	—	—
Infarction	—	2	2
	5	17	10

certainty whether a stenosis is associated with a significantly reduced blood supply (BROWN et coll BREST et coll 1962 HUNT et coll 1962 VERTES et coll 1964) Angiographic examination is indicative of a haemodynamically important stenosis if the passage of contrast medium is definitely prolonged If this is to be evaluated the concentration of medium must be the same in both renal arteries which seldom occurs

If stenosis leads to the formation of collaterals it should be haemodynamically significant It is true that certain authors have pointed out that collaterals can develop (GOLDBLATT 1948 BLAND et coll 1952 POUTASSE et coll 1961 MORRIS et coll 1962 AMPLATZ 1964 WONG & CHOW 1964) Despite this the collateral circulation has not been taken into account in evaluating the stenoses Since collaterals were present in 26 % of the atherosclerotic stenosis in the present series it may be presumed the constriction was of haemodynamic importance at any rate in a quarter of the cases

In occlusion of an artery the collateral circulation is probably the factor which elicits hypertension If the blood supply is so severely impaired that total infarction occurs the hypertensive substances cannot be formed or carried away A prerequisite for renovascular hypertension is viability of the renal tissue If collaterals have time to develop they prevent total infarction and are in this way an indirect cause of hypertension MORRIS et coll stated that only a few grams of viable renal parenchyma are necessary to produce renovascular hypertension and that collateral circulation through the cortex almost invariably suffices in this respect Considerably larger parts of the parenchyma will be viable if a collateral circulation arises from extrarenal vessels via capsular arteries to distal parts of the main trunk or to large branches of the main renal artery (BROLIN & STENER 1966)

It is presumably the same collateral effect that allows infarctions to produce

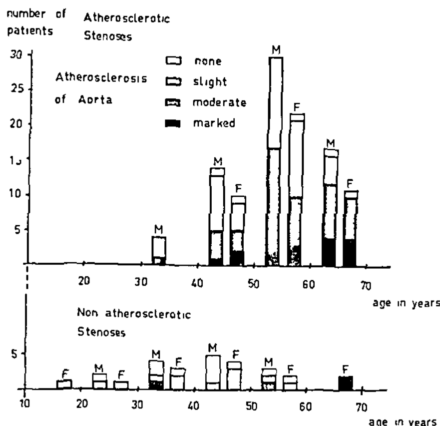


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in the literature A conceivable explanation is that the existence of arterial and arteriolar sclerosis prevents the formation of collaterals

Also with aneurysms both normotensive and hypertensive cases have been reported In view of the confusion about the nomenclature certain authors have counted poststenotic and aneurysmal dilatation associated with fibro muscular hyperplasia as aneurysms (POUTASSE 1957 DUX & THURN 1962) POUTASSE thus reported relatively many hypertensive cases with aneurysm that became normotensive after operation MILTON (1962) in an analysis of 143 published cases found that those with a patent aneurysm were normotensive whereas those in whom the aneurysm was constricted by a thrombus or occluded and the blood supply was through a collateral vessel had particularly high blood pressure If an aneurysm should cause hypertension it must produce narrowing of the main renal artery either by thrombosis (THOMPSON & SMITHWICK 1952) or by extension of a mural calcification in the aneurysm to the renal artery (MILLER & GARVAN 1957 MATHE 1959)

Fibromuscular hyperplasia has characteristic features both pathologically and angiographically (PALUBINSKAS & WYLIE 1961 WYLIE et coll 1962) The cases of fibrous stenosis previously reported do not exhibit the same uniform appearances (McCORMACK 1961 D ABREU & STRICKLAND 1962 HUNT et coll 1962 SUTTON & GUTHRIE 1963 WOOD & BORGES 1963) The changes may be located either periadventitially or in the intima The periadventitial stenoses are of varying aetiology e g bands from the diaphragmatic crura with a high origin of the main renal artery (D ABREU & STRICKLAND) and constricting bands from the lumbar sympathetic trunk (SUTTON & GUTHRIE)

Intimal fibrous proliferation occurs in the presence of various pathologic vascular changes including atheromatosis (SUTTON & GUTHRIE) The lesion described by McGORMACK as idiopathic stenosis of the renal artery seems to be a special form thus in four cases he found excessive infolding of the internal elastic lamina The case in the present series with a well defined intimal fold bulging into the lumen (p 405) might be one of this type However since histological verification is still lacking it is too early to state that this case and the others in the series with fold like narrowings represent a special pathologic change Although they may be an atypical form of atherosclerosis their site argues against this interpretation Thus in no case was the orifice involved but the lesion was situated distal to it

The pathologic changes in fibromuscular hyperplasia and fibrous stenosis in contrast to atherosclerotic stenosis are confined to the renal arteries It is consequently much more probable in these cases that stenosis of renal arteries is in fact the cause of hypertension It is true that this is not reflected in the present operated cases but the series is a small one When accounting

Table 5

Results of operation in relation to the existence of collateral circulation

	Normotensive	Improved	Unchanged
With collateral circulation			
Atherosclerosis	3	4	2
Others	1	2	—
	4	6	2[1]
No collateral circulation			
Atherosclerosis	—	4	4
Others	1	7	4
	1	*11*	*8*[2]

[1] In one case stenosis of unoperated renal artery as well
[2] In three cases stenosis of unoperated renal artery as well

hypertension Occasional cases have been described in which a relation was present between infarction and hypertension (BOYD & LEWIS 1938, FISHBERG 1942, PRINZMETAL et coll 1942, BEN ASHER 1945, WAINWRIGHT 1949, HOWARD et coll 1953, POUTASSE 1956, HALLER et coll 1957, DEFRICK & TYSON 1961) However, in an autopsy series of 205 cases, only 34 % had a history of pressure above 140 mm Hg systolic and 90 mm diastolic (HOXIE & COGGIN 1940) It has been stated that hypertension is caused by the presence, in the border line between infarction and healthy renal parenchyma, of viable tissue with a decreased blood supply (ARNOLD et coll 1951, CONNOR et coll)

It has not been pointed out earlier that a collateral circulation may also arise in occlusion of the branches of the main renal artery GRAVES (1954) studied the vascular distribution in the kidney with an injection procedure and was unable to demonstrate any anastomoses between peripheral branches of the main renal artery These studies were however made in healthy kidneys in which the anastomoses are probably of such small calibre that they cannot be depicted It is evident from the case illustrated in Fig 14 that under pathologic conditions collaterals may be formed between peripheral branches probably not directly but via anastomosing arteries in the calyces and renal pelvis It is therefore conceivable that also in occlusion of peripheral vessels a collateral circulation may arise and produce hypertension

It is impossible to answer the question of why not all infarctions are delimited by a viable zone with decreased blood supply, or why collaterals do not invariably develop In the series of HEITZMAN & PERCHIK (1961) the normotensive cases had a higher mean age than the hypertensive cases in other series

In fibromuscular hyperplasia and periadventitial fibrosis the lesion is situated more distally than atherosclerosis Since these stenoses are confined to the renal arteries the probability that they will cause renal hypertension is greater than in atherosclerotic stenosis

It is consequently important in the evaluation of the results of angiographic examinations to distinguish between atherosclerotic and non atherosclerotic stenoses

SUMMARY

An account is given of various forms of pathologic changes in the renal arteries of 91 men and 73 women with hypertension It is pointed out that angiographically demonstrable stenosis is not necessarily the factor responsible for hypertension The various types of lesions producing hypertension are discussed

ZUSAMMENFASSUNG

Verschiedene Formen von pathologischen Gefassveranderungen in den Nierenarterien bei 91 Mannern und 73 Frauen mit Hypertension werden beschrieben Es wird darauf hingewiesen dass die angiographisch darge tellten Stenose nicht unbedingt die Ursache des Hochdruckes sind Die verschiedenen Lasionen welche Ho hdruck verursachen werden diskutiert

RESUMÉ

L auteur présente diverses formes de modifications pathologiques des artères rénales chez 91 hommes et 73 femmes atteints d hypertension Elle souligne que la sténose mise en évi dence par l angiographie n est pas nécessairement le facteur responsable de l hypertension Elle examine les différents types de lésions qui produisent une hypertension

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for the results of operation, other authors have not distinguished between atherosclerotic and non atherosclerotic stenosis, with the exception of PALUBINSKAS et coll who stated that the results are considerably poorer in the former cases

It is thus obviously of value if the roentgenologist can establish that the stenosis is non atherosclerotic in nature Fibromuscular hyperplasia is easy to diagnose, in view of its characteristic appearances Funnel shaped narrowing distal to the orifice in young patients should suggest that it may be periadventitial fibrosis

Arteritic lesions of the renal arteries are rare EHRLICH et coll (1953) described a case with bilateral narrowing of the orifice in mesaortitis of unknown origin DAKARAJ & WONG (1959) reported similar lesions in two children, and expressed the view that it was a variant of the disease known as primary arteritis of the aortic arch, or Takayashu s syndrome Such an aetiology is conceivable in the case described by the present author (p 405) Since in the aforementioned cases in the literature the arteritic lesions were situated in the aortic wall around the orifices of the renal arteries, they may have been responsible for the renal hypertension Bilateral stenosis of the main renal artery was a component of a widespread vascular disease in the case described in this paper and it is therefore more doubtful whether it was *the cause of hypertension Operation may however be indicated as a vital* measure, as in some cases of atherosclerosis with bilateral stenosis, since the impaired blood flow leads to renal insufficiency and uraemia

Conclusions

Atherosclerotic stenosis is the most common of the various pathologic changes in the renal arteries It is localized to the orifice or the proximal part of the main trunk, in many cases both renal arteries as well as the aorta are involved *Angiographic* examination alone cannot establish whether or not the stenosis implies a decreased blood supply to the kidney Delayed passage of contrast medium and the presence of collaterals are nevertheless strong indications that the stenosis is haemodynamically significant

In occlusion of the main trunk or peripheral branches, a collateral circulation prevents total infarction, and may thereby produce *renovascular hypertension* In the presence of infarction there may be a viable borderline zone with impaired *blood supply which can be responsible for hypertension*

If an aneurysm is to be regarded as the cause of hypertension, it should be combined with some lesion narrowing the orifice of the renal artery, e g a thrombotic deposit or an extension of a calcification

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Fig 1 Aortography arterial phase No changes demonstrable in right kidney The left renal artery is considerably more narrow than the right the intrarenal arterial branches have an arched appearance

Urography A large soft tissue mass at the site of the left kidney extended below the crista iliaca it contained small calcifications in its upper medial part No excretion of the left kidney nor any nephrographic effect were observed The right renal pelvis and ureter were normal

Aortography and *selective left nephroangiography* (Figs 1—2) The left renal artery was considerably narrower than the right and the intrarenal branches of the left kidney which was enlarged had an arched appearance No tumor vessels were evident In the nephrographic phase small areas with very thin contrast loading and large rounded defects were observed Normal conditions were present on the right side As the angiographic appearance pointed to cystic formations in the left kidney renal punctures were performed at several different sites (Fig 2c) the cystic content was clear and yellowish Urografin and carbon dioxide were injected into the cystic formations some of which were intercommunicating the walls were regular and smooth

Left nephrectomy was performed and a mass weighing 1 750 g and composed of a large number of cystic formations was removed (Fig 3) Polyps and cysts were evident in the left ureter

Microscopy (Hild Hansson) Kidney with multiple cysts covered with a single celled layer of cubic epithelium without atypical cells Sclerotic connective tissue lay between the cystic lumina Some hyaline glomeruli and small duct lumina with cubic small-celled epithelium were evident in a few places directly under the capsule Occasional small clumps of lymphocytes Immediately beneath the very thick cell poor and sclerotic capsular connective tissue some

FROM ROENTGENDIAGNOSTIC DEPARTMENT III (DIRECTOR O BARTLEY) AND MEDICAL DEPARTMENT III (DIRECTOR T LINDQVIST), SAHLGRENSKA SJUKHUSET, GOTHENBURG, SWEDEN

MULTICYSTIC RENAL DISEASE IN AN ADULT

by

O BARTLEY, G CEDERBOM and B HEGNELL

Cystic renal changes may be acquired or congenital The former usually occur in the form of solitary or multiple, single or multilocular renal cysts It is recognized that primarily solid tumors, such as hypernephromas, may be partially cystic due to degenerative changes Cysts are sometimes also observed e g with xanthogranulomatous pyelonephritis (AVNET et coll, FRIEDENBERG & SPJUT)

There are two different forms of congenital cystic renal changes, namely polycystic and multicystic, the latter type being called 'Knollenniere' in the German literature According to IVEMARK, the multicystic renal conditions comprise a form of renal dysplasia in which cystic formation dominates A case of a patient with unilateral congenital cystic renal disease is now reported

Case report

A 59 year old woman was *admitted with hemorrhage due to polyps of the corpus uteri* and a palpable mass on the left side of the abdomen and albuminuria No family history of renal disease

Submitted for publication *17 August 1965*

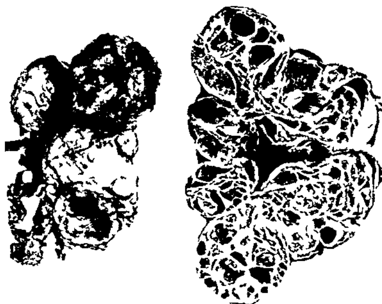


Fig 3 Specimen The renal shape is not maintained and the parenchyma cannot be clearly seen The kidney consists of a large number of irregularly sized cystic formations and any renal pelvis cannot be identified

other member of the family The shape of the kidney is maintained and the renal pelvis and ureter are normal except where the cystic formations extend into and deform the renal pelvis Cystic formations often occur in other organs particularly the liver and pancreas

The renal changes are almost always bilateral and certain authors (e g OPPENHEIMER et coll) state that this is always the case BELL on the other hand believes that unilateral polycystic kidney occurs quite often Moreover in addition to his own cases he has considered ones from the literature and suggests that polycystic kidney is unilateral in 8 % of cases The descriptions of the patients given by BELL and his cited authors are so incomplete that the reader in most instances can draw no conclusions about the type of renal disease involved Some of the cases described in detail could easily have been cases of renal cysts and not of cystic kidney Moreover since BELL neither mentions nor discusses multicystic renal disease some patients with this malformation may have been included in his material There therefore seems to be a good reason for assuming that the frequency of unilateral polycystic renal disease is considerably lower than proposed by BELL DALGAARD has also

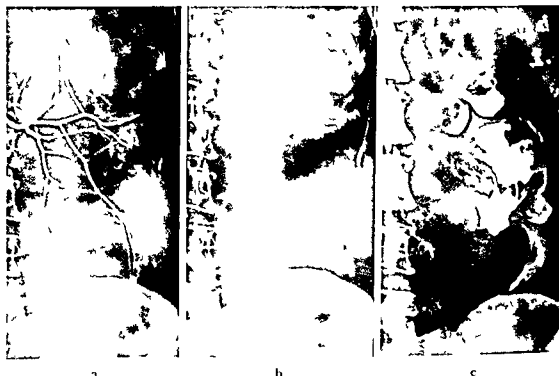


Fig 2 a) and b) Selective left renal arteriography arterial phase (a) and nephrographic phase (b) Thin contrast loading particularly at the lower pole rounded contrast defects c) Puncture of the cyst formations and injection of Urografin and carbon dioxide Some of the cysts intercommunicate they have smooth regular walls

thick walled capillaries and veins were present The ureteric lumen was filled with polypoid formations covered with a transitional small celled epithelium A number of large cyst formations similar to v Brunn s epithelial cysts were observed The musculature in the ureteral wall appeared hypertrophic No inflammatory cell infiltration was present in the mucous membrane No malignancy The right kidney was palpated at operation and was not abnormal

The patient made an uneventful recovery She had normal blood values and normal renal function Serum creatinine before operation was 1 0 mg % and for about one and a half year following operation it varied between 1 0 and 1 2 mg % The concentration capacity varied between 745 and 985 milli osmol / liter The blood pressure was normal the whole time

Discussion

Polycystic renal disease is relatively common Frequency figures obtained from autopsy material of adults vary in the literature between about 0 1 % (Braasch et coll) and 0 5 % (Pabst) Dalgaard has described the condition in detail It is predominantly hereditary and not sex linked, in 70 % of Dalgaard s material of polycystic renal disease, it also occurred in at least one

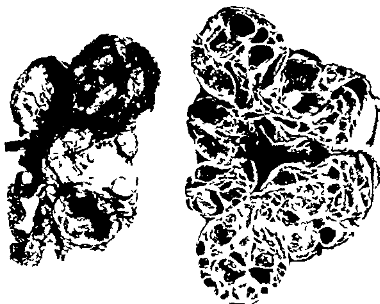


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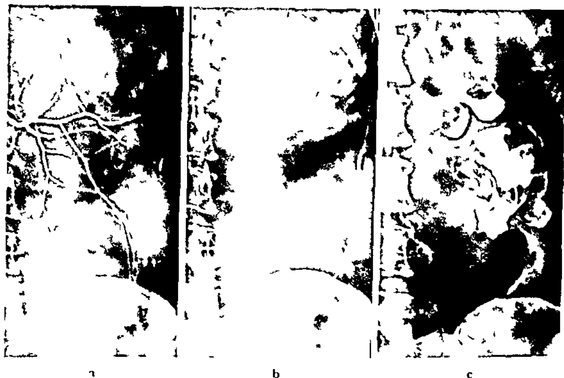


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mation of a degenerated hypernephroma Further information of differential diagnostic value might be obtained by cystoscopy or by an attempt at retrograde pyelography Demonstrable ureteric changes in combination with the absence of a renal pelvis as well as no sign of a ureteric orifice may lend additional support for a diagnosis of multicystic renal disease

SUMMARY

Multicystic renal disease in an adult patient is reported The roentgenologic changes are described and the differential diagnosis is discussed

ZUSAMMENFASSUNG

Ein Fall von Knollenniere bei einem Erwachsenen wird angegeben Das Rontgenbild und dessen Differentialdiagnose werden erlautert

RÉSUMÉ

Présentation d un cas de maladie multikystique du rein chez un adulte Description des s gnes rad ologiques et discussion du diagnostic différentiel

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arrived at this conclusion. Many authors, among others BARNETT, have described cases, primarily considered unilateral, in which changes have been observed in the other kidney many years later. In these instances, angiography has not been used for the diagnosis, however.

Multicystic renal disease is probably very uncommon and up to now reports on only about 20 adult cases have been published. According to CRAIG, no hereditary pattern could be demonstrated in these cases, nor could it be ascertained in the considerably more common infantile form. According to the same author, the disease occurs somewhat more often on the left than on the right side and rather more frequently in men than in women. All adult patients with multicystic renal disease have had unilateral renal changes. In the light of the extraordinary lack of renal parenchyma in this condition, bilateral changes could hardly be expected in adults. The shape of the kidney never persists, an identifiable renal pelvis is absent and various ureteric changes frequently occur (PARKULAINEN et coll., SPENCE, VELLIOS & GARRET). In infants with multicystic kidneys, other malformations have frequently been observed, e.g. in other parts of the urinary system as well as in the heart, blood vessels, and oesophagus (PARKULAINEN et coll.). These findings strongly support the assumption that multicystic renal disease, unlike the polycystic form, is a congenital malformation acquired in utero.

Histologic examination of multicystic kidneys from adults sometimes reveal dysplastic structures with primitive glomeruli and tubules. The number of glomeruli is very small. To judge from the literature, no other distinct histologic differences between multicystic and polycystic changes in the adult kidney exist.

Comparison of the characteristics of the present case with those of the two conditions discusssed suggests that they are essentially in accord with those of multicystic renal disease.

Urography has previously been carried out in patients with multicystic renal disease, and contrast excretion has never been observed, but knowledge of earlier angiographic appearances seems to have been lacking, however. Apart from the fact that the changes demonstrated were unilateral the appearances agreed in principle with those obtained in polycystic renal disease. The contrast loading was, however, considerably less than is usually observed with the latter condition, because the kidney had almost no renal parenchyma. Absence of excretion at urography, and similar angiographic appearances may be present in conditions such as hydronephrosis, cystic hypernephroma without tumor vessels, and xanthogranulomatous pyelonephritis. Renal puncture (of the renal pelvis or the cysts) ought to be of value in the differential diagnosis. Even with this method, however, it may be difficult to exclude for

to an undesirably high value A solution containing 50 03 % sodium metrizoate 10 96 % methylglucamine metrizoate 2 56 % calcium metrizoate and 1 80 % magnesium metrizoate was used for the test The iodine content was 370 mg/ml i e the same as for Urografin 76 %, and the viscosity was 3 81 cP/37

Identical injections of this contrast medium and Urografin 76 % were made in 22 patients at coronary angiography The pressure in the injector was so adjusted that the same amount of iodine per unit of time was delivered into the aorta with the two contrast media The dose of each medium was approximately 1 ml/kg bodyweight Every second time the first injection was made with the Isopaque preparation and every second time Urografin 76 % was used for the first injection The order of injections caused no observable difference

The subjective sensations experienced by the patients were compared, they app-ared to be more severe in seven patients after Isopaque and in three after Urografin whereas no difference was noted in twelve patients It is obvious than an Isopaque preparation containing methylglucamine metrizoate must produce more symptom than Urografin 76 %, but the difference was less striking than in the exp riments with Isopaque B 60 % It seems that the symptoms were less noteworthy than after the injection of the original Isopaque B 60 % There were no very severe reactions in the 22 patients now examined as may be seen from the data tabulated below but the other minimal side effects were similar

Side effects	*Isopaque with 11 % methylglucamine metrizoate*	*Isopaque 60 %*
None or negligible	5	3
Slight	7	21
Moderate	9	32
Severe	1	7
Very severe	—	3
Number of patients	22	66

The diagnostic value of the two contrast media was also similar as judged by a comparison of the quality of the coronary angiograms obtained

It appears that the sub titution of a comparatively small amount of sodium metrizoate with methylglucamine metrizoate in Isopaque 60 % reduces the subjective side effects The result of a larger addition would be a matter of pure conjuncture but it would seem desirable to compromise in order to balance the side effects against the necessity for a medium of relatively low viscosity

FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR: PROF. FOLKE KNUTSSON) OF THE UNIVERSITY HOSPITAL, UPSALA, SWEDEN

INFLUENCE ON SUBJECTIVE SIDE EFFECTS OF ADDING METHYL GLUCAMINE METRIZOATE TO ISOPAQUE 60 %

A comparative clinical study

by

LARS BJORK

The present author has reported (BJORK 1964) that Isopaque B 60 % (55.2 % sodium metrizoate, 2.5 % calcium metrizoate and 2.0 % magnesium metrizoate) (Nyegaard & Co, A/S, Oslo) produces more discomfort in coronary angiography than Urografin 76 % (Schering). This is mainly due to a much more intense sensation of heat felt after the injection of Isopaque B than after a corresponding injection of Urografin 76 %. The pain may sometimes be severe enough to make the patient reluctant to undergo further investigations of similar type. The diagnostic value and the minimal side effects of the two contrast media are similar.

It is known that the addition of a methylglucamine salt to a contrast medium may decrease its toxicity (GENSINI & DI GIORGI 1964, PORTSMANN 1965). It was therefore considered of interest to investigate the effect upon the subjective sensations of patients of the addition of a comparatively small amount of such a substance to Isopaque. It was thought desirable to keep the amount as low as possible in order not to increase the viscosity of the preparation

Submitted for publication 7 February 1966

FROM THE NATIONAL CHILDREN'S CARDIAC HOSPITAL, MIAMI, FLORIDA, U S A

ANGIOCARDIOGRAPHIC DETERMINATION OF SIZE OF LEFT ATRIUM IN CONGENITAL HEART DISEASE

by

A CASTELLANOS and F HERNANDEZ

The precise determination of the left atrium is most important in the diagnosis of congenital and acquired cardiac diseases This chamber increases in size in patent ductus arteriosus and ventricular septal defect as well as in lesions of the mitral valve Fluoroscopic and conventional studies have so far been very useful for this purpose and many roentgenographic signs have been described Nevertheless it is well known that in some cases especially in slight enlargement of this chamber these methods sometimes fail The authors have therefore attempted to measure it by means of angiocardiography during the levo phase of venous angiocardiography it is well filled The logical method of estimating the area (cm^2) of the chamber during diastole rather than systole has been applied for assessing its size Even recognizing that the delimitation of the left atrium from the pulmonary veins and left atrial appendage is somewhat arbitrary this should not invalidate the result The normal values of the left atrial area were obtained at end diastole so that they could be compared with those in different types of congenital heart disease and practical conclusions drawn

Submitted for publication 16 August 1965

SUMMARY

A comparative study revealed that the substitution of 11 % sodium metrizoate with methyl glucamine metrizoate in Isopaque 60 % at coronary angiography definitely reduced the subjective side effects

ZUSAMMENFASSUNG

Es konnte durch Vergleichsversuche bei Koronarangiographie ermittelt werden dass weniger Nebenerscheinungen hervorgeruft wurden wenn 11 % von Sodium Metrizoat gegen Methyl Glucamin Metrizoat in Isopaque 60 % ersetzt wurden

RÉSUMÉ

Une étude comparative a montré que la substitution de 11 % du métrizoate de méthyl glucamine au métrizoate de sodium dans l Isopaque 60 % réduit notamment les signes fonctionnels qui apparaissent au cours de l angiographie coronarienne

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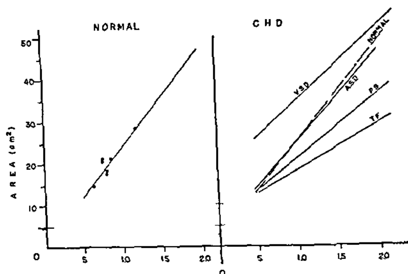


Fig 1 *Left* Correlation between the end-diastolic area of the left atrial cavity and body surface area (m²) regression line in normal cases *Right* Comparison between the normal regression line and those in cases of VSD ASD PS and Fallot's tetrad Only the VSD line lies above normal

to the target and from the latter to the film Prior to the procedure the anteroposterior and lateral diameters of the thorax were measured as well as the presumed distance from the left atrium to the films The patients lay supine on a thick spongy pad

Survey of the material and summary of the findings are tabulated below

		Age in years		BSA in m²		PFI in l/min/m²	
	Cases	Range	Mean	Range	Mean	Range	Mean
Normal	10	5.5—31	9.5	0.74—1.81	0.97		
VSD	32	4.0—25	9.0	0.64—1.41	0.94	4.8—21	9.0
ASD	30	4.0—47	10.8	0.63—1.75	1.07	3.0—23	10.7
PS	21	4.5—35	12.7	0.62—1.80	1.03	1.6—6.2	3.5
T of F	17	0.3—43	7.1	0.30—1.61	0.75	1.4—4.4	2.5

Definition VSD = ventricular septal defect ASD = atrial septal defect PS = pulmonary stenosis and T of F = Fallot tetrad

Results

Normal cases Ten normal cases were studied by measuring the end diastolic and end systolic areas of the left atrium in anteroposterior projections (Table I) The results were plotted against the BSA (m²) and a direct relationship was found The linear regression equation was determined

$$Y = a + bX = 1.2388 + (23.5331)X \quad r = 0.987$$

Table 1

End systolic and end diastolic area of left atrium in normal cases

Case Nos	Age	SA m²	Systole cm²	Diastole cm²	Remarks
1	31 0	1 96	24 4	48 5	Innocent murmur
2	5 [illegible]	0 78	9 3	18 1	Right sided aorta
3	4 5	0 74	10 1	20 6	Anomalous origin of subcl artery
4	11 0	1 16	14 6	28 4	Aneurysm of r coronary artery
5	5 5	0 74	12 6	21 4	Innocent murmur
6	7 5	0 77	8 2	19 0	Innocent murmur
7	6 0	0 73	8 9	18 5	Right sided aorta
8	5 5	0 83	10 6	21 3	Innocent murmur
9	5 5	0 62	7 3	14 8	Innocent murmur
10	13 0	1 36	13 8	31 0	Innocent murmur

Material and Method Ten normal cases and 100 cases of congenital heart disease of various kinds were studied Venous angiocardiography was performed in all cases, injection of the contrast medium being made into the right atrium, right ventricle, or into the pulmonary artery or its branches Hypaque 75 % was used, 1 0 to 1 5 ml being injected automatically with the Cordis injector (pressure ranging from 300 to 700 lbs) A Schonander biplane film changer was used in most cases with 3 to 5 exposures per second during the levo phase Only the measurements obtained in anteroposterior projection were considered

Simultaneous electrocardiographic recordings and roentgenograms were effected by means of a Sanborn Poly Viso, which enabled each film to be correlated with the phase of the cardiac cycle at which it was obtained Even cases that developed arrhythmia during the dextro phase of the procedure were taken into consideration since these did not interfere with the results in the levo phase Routine catheterizations were in the majority of cases made prior to the angiocardiographic study Systemic and pulmonary blood flows were estimated by the Fick principle

Areas of the left atrium in anteroposterior projection in end systole and end diastole were determined by a planimeter Correction for distortion due to magnification was determined by comparing the outer diameter of the catheter with its diameter as it appeared in the films A piece of lead of known area was also placed at different distances from the film, roentgenograms were taken, the magnification was estimated and a percentage recorded The latter ranged from 10 % to 30 % according to the distance from the roentgen tube



Fig 3 Same case as in fig 2 Levo-angiocardiogram in which the left atrium appears at end-diastole with an area below normal (?0 3 cm²) BSA 1 4 m² PFI ? 6 l/min/m² TPR 1 825 dynes/sec/cm

Ventricular septal defect This is a heterogenous group One case (Case 28) had isolated dextrocardia and four (Cases 3 11 12 and 25) had high pulmonary vascular resistance Case 12 also had a large patent ductus arteriosus (Figs 2 and 3) Cases 2 5 14 and 16 were considered as cases of combined increased shunts and increased pulmonary vascular resistance The systolic pressure of the main pulmonary artery was above 80 mm Hg and the pulmonary flow indices (PFI) were 7 10 10 and 7 6 l/min/m² respectively Case 8 had equal pulmonary and systemic systolic pressure a PFI of 16 3 l/min/m² and 7 1 min m of left to-right shunt and pulmonary vascular resistance of 589 dyne sec cm The left atrial end diastolic area was above normal (72 5 cm² Fig 5) in Fig 5b the high pulmonary pressure was considered to be related to a large pulmonary flow index Case 4 was one of mild mitral insufficiency Fig 6) and the area of the left atrium was above normal (72 5 cm² Some degree of mitral insufficiency was also present in Cases 8 and 15 Seven cases had variable degrees of pulmonary stenosis (Cases 6 10 17 18 20 29 and 32) Partial anomalous drainage of the right pulmonary veins was



Fig 2 Dextro angiocardiogram in ventricular s ptal defect with patent ductus arteriosus and high pulmonary resistance I eversal of flow through the patent ductus is clearly s en

The study of this regression equation means that if the body surface area is multiplied by 23 5 the result gives an approximate left atrium area (in cm^2) in the anteroposterior projection

The ratio of the end diastolic area to the end systolic area varied from 1 1 7 to 1 2 3 with an average of 1 2

Congenital h art diseases One hundred cases were studied, 32 having ventricular septal defect, 30 atrial septal defect, 21 pulmonary stenosis, and 17 cases Fallot s tetrad

When plotting the end diastolic area of the left atrium against the body surface area *of the patients in the above types of congenital malformations* a direct relationship was found Linear regression equations were determined

Ventricular septal defect	$Y = a + bX = 11\ 7877 + (20\ 2193)$
	$r = 0\ 4968$
Atrial septal defect	$Y = a + bX = 2\ 9483 + (21\ 7649)$
	$r = 0\ 8231$
Pulmonary stenosis	$Y = a + bX = 5\ 4193 + (16\ 0952)$
	$r = 0\ 8341$
Fallot's tetrad	$Y = a + bX = 5\ 6305 + (13\ 248)$
	$r = 0\ 7792$



Fig 3 Same case a n fig ? Levo-angioca diog am in which the left atrium appears at end d a tole w th an area below normal (20 3 cm) BSA 1 4 m PFI ? 6 l/min/m TPR 1 8?5 dynes/ sec/ cm

Ventricular septal defect This is a heterogenous group One case (Case 28) had isolated dextrocardia and four (Cases 3 11 12 and 25) had high pulmonary vascular resistance Case 12 also had a large patent ductus arteriosus (Figs 2 and 3) Cases 2 5 14 and 16 were considered as cases of combined increased shunts and increased pulmonary vascular resistance The systolic pressure of the main pulmonary artery was above 80 mm Hg and the pulmonary flow indices (PFI) were 7 10 10 and 7 6 l/min/m² respectively Case 8 had equal pulmonary and systemic systolic pressure a PFI of 16 3 l/min/m² and 7 l/min/m of left to right shunt and pulmonary vascular resistance of 389 dyne/sec/cm The left atrial end diastolic area was above normal (72 5 cm²) (Fig 5) in Fig 5b the high pulmonary pressure was considered to be related to a large pulmonary flow index Case 4 was one of mild mitral insufficiency (Fig 6) and the area of the left atrium was above normal (72 5 cm) Some degree of mitral insufficiency was also present in Cases 8 and 15 Seven cases had variable degrees of pulmonary stenosis (Cases 6 10 17 18 20 29 and 32) Partial anomalous drainage of the right pulmonary veins was

Table 2

End systolic and end diastolic area of left atrium in ventricular septal defect

Case Nos	Age	SA m²	BSA		PFI l/min/m²	PBF l/min	Remarks
			Syst cm²	Diast cm²			
1	10 0	1 09	17 4	30 0	4 8	5 2	
2	8 0	1 01	18 9	31 0	7 0	7 1	Increased flow and resistance*
3	25 0	1 50	20 3	22 5	2 4	3 6	High pulmonary resistance
4	12 0	1 53	51 3	72 5	12 4	19 0	MI
5	7 0	0 60	20 0	27 7	10 0	6 0	Increased flow and resistance*
6	7 5	0 80	16 3	27 7	6 8	5 4	PS and AS
7	2 5	0 40	16 7	27 2	21 0	8 4	
8	12 0	1 09	43 6	58 6	16 3	17 8	MI
9	6 0	0 73	15 7	20 1	8 1	5 9	
10	15 0	1 50	27 9	43 4	7 3	10 9	PS
11	11 0	1 00	23 0	28 5	4 8	4 8	High pulmonary resistance
12	14 0	1 40	18 2	20 3	2 6	3 6	» » »
13	3 5	0 68	11 3	18 8	10 0	6 8	
14	2 5	0 51	15 7	23 6	10 0	5 1	Correction transposition of great vessels increased flow and resistance*
15	8 0	0 92	48 9	65 4	12 0	11 0	Correction transposition of great vessels and MI
16	10 0	0 90	21 8	33 4	7 6	6 8	Correct transposition of great vessels increased flow and resistance
17	18 0	1 80	35 4	45 5	8 8	15 8	PS
18	5 5	0 80	15 1	19 3	6 5	5 2	PS
19	16 0	1 41	26 8	49 1	17 0	23 9	
20	8 5	0 97	14 0	23 4	4 7	4 6	PS
21	5 0	0 76	17 4	25 8	6 4	4 9	
22	5 0	0 68	12 3	21 5	14 0	9 5	
23	5 5	0 65	17 2	23 9	8 8	5 7	
24	6 5	0 80	25 7	37 2	12 0	9 6	Anom drainage of PV
25	24 0	1 25	18 0	22 8	—	—	High pulm resistance
26	5 5	0 66	[illegible]	19 7	5 5	3 6	
27	6 0	0 83	16 2	24 4	5 1	4 2	
28	7 5	0 86	13 0	18 8	5 6	4 8	Dextrocardia
29	5 0	0 76	14 6	19 8	5 5	4 [illegible]	PS
30	4 0	0 64	20 1	[illegible]4 0	24 0	—	
31	4 0	0 64	18 7	23 6	—	—	
32	8 0	0 92	21 4	33 1	12 0	11 0	PS

* Combined type in which increased flow appeared to be associated with increased pulmonary vascular resistance

Table 3

End systolic and end diastolic area of left atrium in atrial septal defect

Case Nos	Age	SA m	BSA Syst cm	Dist cm	PFI l/min/m²	PBF l/min	Remarks
1	5.5	0.68	14.0	20.3	8.4	5.7	
2	6.0	0.81	12.2	18.4	6.0	4.9	
3	42.0	1.88	41.7	46.4	10.9	20.5	Anom. drainage of PV
4	6.0	0.84	16.3	18.9	21.0	17.6	
5	13.0	1.14	[illegible]	31.9	5.4	6.2	Coarct. of RPA and LPA
6	5	0.73	21.0	22.6	5.8	4.2	Anom. drainage of PV
7	12.0	1.05	17.1	22.0	21.0	22.0	Anom. drainage of PV
8	11.5	1.20	15.9	18.3	3.0	3.6	High pulm. resist.
9	5.0	0.74	3.4	12.2	4.5	3.3	High pulm. resist.
10	11.0	0.99	17.6	26.3	8.3	8.2	
11	8.0	0.90	23.1	26.1	11.0	9.9	
12	8.0	0.50	22.3	25.3	10.0	9.0	
13	6.0	0.88	19.8	22.2	16.9	14.9	
14	19.0	1.40	26.9	30.3	12.0	16.8	Anom. drainage of PV
15	4.0	0.63	12.1	15.9	9.0	5.7	Anom. drainage of PV
16	16.0	1.50	22.2	29.7	9.2	13.8	
17	12.0	1.21	21.3	30.6	8.7	10.5	Anom. drainage of PV
18	9.5	0.98	19.5	27.9	6.2	6.1	
19	19.0	1.5	4[illegible].1	45.3	16.5	25.6	Anom. drainage of PV
20	17.0	1.57	27.2	35.0	7.1	11.1	
21	5	0.79	19.2	25.2	15.9	12.6	Anom. drainage of PV
22	15.0	1.59	36.9	34.6	12.0	19.0	
23	6.0	0.73	14.7	[illegible]0.6	1[illegible].9	9.4	VSD
24	17.0	1.50	19.8	[illegible]1.6	—	—	High pulm. resistance PDA
25	5.5	0.70	1[illegible].6	15.5	3.6	2.5	High pulm. resistance
26	5.0	0.72	16.3	18.8	8.3	6.0	
27	4.0	1.75	35.6	40.1	4.0	7.0	PS
28	14.0	1.28	23	30.8	13.0	16.6	
29	9	0.98	17.2	26.1	6.6	6.5	
30	5.5	0.72	11.6	16.3	16.3	11.7	Anom. drainage of PV

found in Case 24. Corrected transposition of the great vessels were present in Cases 14, 15 and 16.

Fig. 7a is a scatter diagram correlating the BSA with the end diastolic area of the left atrium in cases of VSD. It indicates that three out of four cases with high pulmonary resistance had a small left atrium while all those with elevated pulmonary pressure associated with high pulmonary flow index appear to have had values above normal.



Fig 4 Case of ventricular septal defect corrected transposition of the great vessels and mitral insufficiency large left atrial cavity exposure made at end atrial diastole Area of left atrium 65 4 cm² (above normal) PFI 12 0 l/min/m² *left to right shunt 7 6 l/min/m* BSA 0 90 m²

The three cases with significant mitral insufficiency were found to have the largest areas of the left atrium in this series Direct relationship was evident between both parameters and the majority of the observations (81 25 %) had areas above normal limits, with exception of six cases, three of which had high pulmonary vascular resistance, and one with significant degree of pulmonary stenosis

Atrial septal defect Four cases (Cases 8, 9, 24 and 25) of high pulmonary resistance are included in Table 3, Case 24 also had a PDA Valvular pulmonary stenosis was present in Case 27 There are nine cases (Cases 3, 6, 7, 14, 15, 17 19, 21, and 30) with different types of partial anomalous drainage of PV, Case 23 is one of a ventricular septal defect

Fig 7b is a scatter diagram with correlation between the body surface area and the end diastolic area of the left atrium Eleven out of 30 cases of this group (36 %), were found to have a left atrium smaller than normal Of the four cases with high pulmonary vascular resistance, three had the smallest areas of the group Nevertheless, the regression line falls very close to the normal one

Pulmonary stenosis There are four cases of infundibular type in Table 4 the remainder are valvular Fig 8a is a scatter diagram with correlation between

Table 4

End systolic and end diastolic area of left atrium in pulmonary stenosis

Case Nos	Age	SA m	BSA		Systolic pressure in mm Hg		PFI l/min/m²	PBF l/min	Remarks
			Syst cm	Diast cm	RV	PA			
1	4 5	0 77	15 0	18 3	165	19	1 8	1 4	Valv PFO
2	6 5	0 83	13 7	20 4	90	14	2 5	2 1	Valv PFO
3	6 0	0 74	8 5	11 7	125/ 36	36	3 1	2 3	Inf PFO
4	11 0	1 20	17 4	25 0	64	22	3 0	3 6	Valv PFO AS
5	5 5	0 70	12 4	20 0	32	23	5 0	3 5	Valv
6	5 5	0 62	5 6	13 9	27	15	4 4	2 7	Valv
7	6 0	0 75	10 3	15 6	95	12	4 0	3 0	Valv
8	8 0	0 78	10 4	18 9	35	17	4 4	3 4	Valv
9	33 0	1 61	27 2	33 3	150	18	1 7	2 7	Valv
10	11 0	1 34	12 2	24 5	150	16	3 0	4 0	Valv PFO
11	6 0	0 88	12 1	20 2	39	18	4 3	3 8	Valv
12	8 0	1 10	20 7	24 9	65	30	6 3	6 8	Valv anom drainage of PV
13	9 0	1 21	20 3	25 0	200	10	1 6	1 9	Valv ASD
14	16 0	1 53	17 1	27 0	40	15	5 3	8 1	Valv L-R
15	5 0	0 84	12 3	15 8	180	32	2 5	2 1	Valv PFO
16	10 0	1 05	12 2	22 3	58	14	4 0	4 2	Valv
17	5 0	0 93	14 2	17 9	100	20	4 0	3 7	Valv
18	23 0	1 43	20 2	29 0	135/ 15	15	2 9	4 1	Inf
19	13 0	1 39	18 1	25 1	115	20	1 7	2 4	Valv
20	35 0	1 80	18 6	29 8	165/115	18	2 5	4 5	Inf
21	35 0	1 27	17 3	36 5	165	18	2 8	3 6	Inf

PFO = patent foramen ovale

the body surface are and the end diastolic area of the left atrium The size of this chamber is smaller than normal in all cases except one of the infundibular and two of the valvular type (83 %) The regression line is below the normal although somewhat less steep

Fallot s tetrad Aneurysmal dilatation of the right pulmonary artery is present in Case 1 in Table 5 Corrected transposition of the great vessels was evident in Cases 2 5 and 6 Case 7 had a coarctation of the left pulmonary artery Case 14 a Taussig Blalock operation on the right side while Case 15 had

Table 5

End systolic and end diastolic area of left atrium in Fallot's tetrad

Case Nos	Age	SA m²	Left atrium Syst cm²	Left atrium Diast cm²	PFI l/min/m²	PBF l/min	Remarks
1	2.5	0.46	5.2	6.8	3.3	1.5	Aneurysmal dilatation of RMPA
2	6.0	0.71	18.0	22.8	3.0	2.1	Corrected transposition of GV
3	6.[illegible]	0.60	9.6	14.4	3.4	2.7	
4	5.0	0.78	14.9	20.5	4.4	3.4	
5	5.0	0.84	9.5	11.2	2.1	1.8	Corrected transposition of great vessels
6	6.[illegible]	0.84	15.4	16.3	2.0	1.7	Corrected transposition of great vessels
7	20.0	1.5[illegible]	19.0	27.3	2.4	3.7	Coarct of LPA
8	2.5	0.51	6.8	12.0	—	—	Right sided aorta
9	17.0	1.22	14.4	18.2	1.3	1.6	
10	7.0	0.80	10.1	15.7	3.4	2.7	
11	1.5	0.50	9.7	14.7	—	—	
12	9.0	0.96	14.0	16.2	1.8	1.7	
13	2.5	0.50	7.6	10.8	—	—	
14	1.5	0.47	6.8	8.9	—	—	PDA
15	15.0	1.29	19.0	24.4	1.7	2.2	Partial anomalous drainage of PV
16	5.0	0.74	12.4	18.6	3.6	2.7	
17	1.[illegible]	0.38	7.6	12.[illegible]	—	—	Right sided aorta

anomalous drainage of the left pulmonary vein, an atrial septal defect and persistency of the left superior vena cava. A right sided aorta was present in Cases 8 and 17.

The pulmonary flow index (l/min/m) and the pulmonary blood flow (PBF) (l/min) were estimated in Cases 1 through 7 and Cases 9, 10, 12, 15 and 17.

The body surface area has been plotted against the end diastolic area of the left atrium in Fig. 8b. Four cases had areas above normal and the remaining 13 cases (70 %) below normal.

The normal regression line is compared with those of the different groups of congenital heart disease studied in Fig. 8b. The regression line is above the normal in ventricular septal defects indicative on an enlarged left atrial cavity. The line for atrial septal defects reveal that the chamber appears to be normal at any value of the surface area. The regression lines in pulmonary



Fig 5 a) Le o ang oca d ogram in frontal project on at end d astole of left atrium in a case of entricular sept l defect A ea of left at um 27 7 cm (slightly inc eased) BSA 0 60 m PFI 10 l min/m TPR 839 dynes/sec/cm Th s is a combined case of some degree of pulmonary v sc lar ob truct on with a moderately elevated pulmonary flow ndex b) Left atrium at end sy tole n the same ase Enla g d left ventr cular chamber and enlarged main pulmonary artery subnormal ao ta

stenosis and Fallot s tetrad are below the normal consistent with a small left atrium It should be pointed out that the area of this chamber is far smaller in the latter than in the former

Correlation with pulmonary blood flow and pulmonary flow index The pulmonary flow index ($l/min/m^2$) was also plotted aginast the end diastolic area of the left atrium in each case of the four group of congenital cardiac lesions that were studied

A direct relationship was apparent in ventricular septal def cts (Fig 9) even though marked scattering was present due to the above mentioned hetero geneity of the group Cases of high pulmonary resistance had areas below normal while those with increa ed pulmonary resistance and an increase in flow were found to have areas above the normal regression line Some degree of mitral insufficiency produced the highest values A fair degree of direct correlation was evident in atrial septal defects (Fig 9) cases with high pul monary vascular resistance had very low values No significant relationship was found to exist in either valvular or infundibular pulmonary stenosis (Fig 9) or in Fallot s tetrad (Fig 9) B cause of the failure to demonstrate

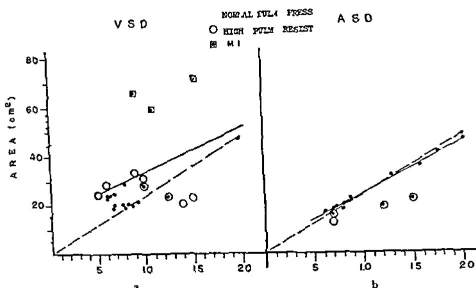


Fig 6 a) Dextro angiocardiogram showing ventricular septal defect Normal pulmonary vascular resistance 96 dynes/sec/cm⁵ BSA 1 53 m PFI 12 4 l/min/m left to right shunt 8 6 l/min/m b) Same case Levo angiocardiogram exposure at the end atrial diastole Enlarged left atrial cavity BSA 1 53 m area of left atrium 72 5 cm²

a direct relationship between the size of the left atrium and the amount of blood flowing through the lesser circulation this study must be considered as unreliable

The pulmonary flow index (l/min/m), plotted against the area of the left atrium corrected for the body surface area (cm²/m) (Fig 10, corresponding to VSD, PS and Fallot s tetrad), revealed a direct relationship This means that the higher the pulmonary flow index the larger the left atrium in these diseases, although if a regression line for each group were obtained the steepness of the slope would be different Fig 10 indicates that in cases of atrial septal defects, if the cases with high pulmonary resistance are excluded, no significant correlation is present, in other words, the area of the left atrium corrected for the body surface area was found to have the same value irrespective of the importance of the pulmonary flow index (l/min/m²)

A direct relationship appeared to be present in all the diagnostic groups when the PBF (l/min) was plotted against the area of the left atrium without correction for BSA (m²) (Fig 11) The most outstanding discrepancy between the former and the latter correlation was evident in the results found in atrial



F g 7 Cor elation between end d astol c area of left atrium and BSA in ventricular septal defect (a) and in t ial septal defect (b) Solid line regress on l ne for each group of cardiac lesions br ken l n normal c cles increased flow with increased res stance Direct relationship between both parameters

s ptal defects B cause the amount of blood flowing through the lesser circula tion in the latter study was not referred to the square meter of body surface the value of the body surface area was influenced This was directly correlated to the total end diastolic area of the left atrium

Discussion

A direct relationship between the body surface area and the left atrial area in normal subjects appears to be established If the *cardiac* weight increases with age the capacity of the left atrium also increases Nevertheless when correction for the body surface area is made (cm^2/m^2) the diastolic area of the chamber will remain constant (23 5 $cm^2 \times m^2$) regardless of the weight and height of the subject (Fig 1)

Estimation of the size of the left atrium aids in the differential diagnosis between isolated ASD VSD and PDA Fluoroscopic studies have firmly established that the left atrium appears to be enlarged in VSD and PDA and normal or subnormal in ASD (ARVIDSSON & ÖDMAN 1957 COBBS SHILLINGFORD & STEINER 1957 GRIBBE HIRVONEN LIND & WEGELIUS 1959 DURANT & METIANU 1963 HEIM DE BALSAC 1953 KANE PETTIT PAPPAS &

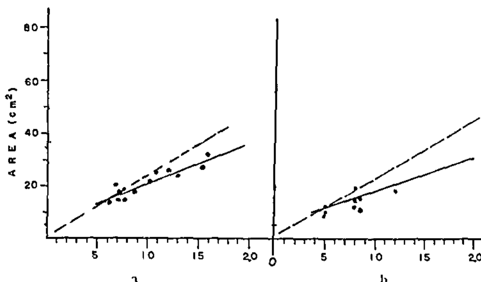


Fig. 8. Correlation between end diastolic area of left atrium and BSA (in m² along abscissa) in pulmonary stenosis (a) and in a case of Fallot's tetrad (b). Broken line = normal regression line; solid line = regression line of each group of cardiac lesions.

Boone 1963, Keith, Rowe & Vlad 1958, Nadas, Rudolph & Hoffman 1960, Taussig 1960). This cavity has often been found to be increased in size in coarctation of the aorta (Astley 1959).

Nevertheless, the accuracy of the diagnosis of the size of the left atrium based on the displacement of the barium filled esophagus has been much discussed. Some authors have recorded it in the RAO position at an angle of 70° while others have preferred a 45 degree angle. Kane et coll. reviewed 30 cases of ventricular septal defects and found three in which the left atrium was wrongly recorded as normal in size. On the other hand, posterior displacement of the esophagus is not pathognomonic of left atrial enlargement because it may occur in cases in which gross enlargement of the right ventricle is present (Schwedel 1946). Moreover, proper roentgenographic evaluation of the left atrium must include a barium swallow examination in different projections, such as study of the elevation of the left main bronchus, and evaluation of the 'double line' in the frontal position, but a slight enlargement of the left atrium may still be missed in spite of these measures. The angiocardiographic evaluation of the left atrium must thus be considered of great value and essentially precise.

Determination of the volume or capacity of the left atrium in systole and diastole by means of a very rapid film changer or of a cine camera, in two projections is another method (Arvidsson 1961, Gribbe et coll., Miller & Swan 1963) and one for which accurate mathematical formulae have been

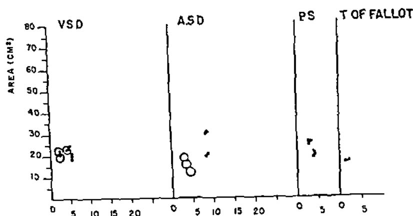


Fig 9 Correlation between PFI (in l/min/m along abscissa) and the end-diastolic area of the left atrium in four groups of congenital heart disease

developed Left ventricular volume as well as hemodynamic data have also been determined (GRIBBE et coll and MILLER & SWAN)

The left atrium is an ovoidelliptical shaped chamber with its major axes lying transversely the major diameter being almost vertical in the lateral view The upper and lower margins of the chamber move away upwards and downwards during diastole and systole but the movement of the lateral borders are much more limited due to their attachment to the pulmonary veins During end diastole the left atrium and its appendage are larger and smaller than during systole Although delimitation of the left atrial cavity at end diastole from both the right and left pulmonary veins and from the left atrial appendage may often be arbitrary the end diastolic area of the chamber is a reliable criterion as to whether it is large normal or small Its borders are sometimes in lateral and oblique projections less precise due to the superimposition of pulmonary veins

The surface measurement of the chamber is determined in cm by means of the planimeter The authors are sceptical about the accuracy of estimating the volume of the left atrium solely by means of a single plane Geometrically the chamber is not a perfect ellipoidal structure and values calculated in this manner are therefore uncertain

The method has also its *limitations* In cases in which the cardiac output is very low (e g in severe pulmonary stenosis and in extreme cases of Fallot s tetrad) and the injection of the contrast medium has been made into the right atrium or even into the inflow *tract of the* right ventricle the left atrium will be faintly and not accurately outlined This also occurs in high pul

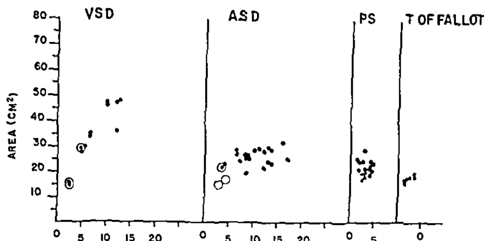


Fig. 10. Correlation between PFI in l/min/m² and the end-diastolic area of left atrium corrected for the BSA (cm²/m²).

monary resistance complicating left to right shunts, due e.g. to ventricular septal defect in which sharp delineation of the left atrium and left ventricle was not possible.

Values above the normal were recorded in 81.2 % of the cases of ventricular septal defect, 64 % of atrial septal defect, 17 % of pulmonary stenosis and 30 % of Fallot's tetrad. It should be stressed that many observation points in the scatter diagram fall very close to the normal line, and evaluated by the classical roentgenographic method they would be considered as normal. It is most important to point out that in both ventricular and atrial septal defects all cases in this investigation with high pulmonary resistance had values below normal. Large left to right shunts were associated with a large atrium. Cases with increased pulmonary vascular resistance and increased flow (NADAS 1960) were found to have areas that fell above the normal regression line. They may be considered as an intermediate stage between cases with high pulmonary pressure associated with high flow (hyperkinetic pulmonary hypertension) and those with high pulmonary resistance and low pulmonary flow. Estimation of the size of the left atrium in these conditions is very helpful in evaluating the hemodynamic characteristics.

The regression line of normal cases compared to those of the group mentioned above illustrates certain points. The fact that the regression line of ventricular septal defect lies above the normal indicates a larger atrial chamber. It should be stressed that this regression line approaches the normal one as the BSA increases. This means undoubtedly that as the subject advances in age, the chamber of the left atrium appears to become relatively smaller. This finding

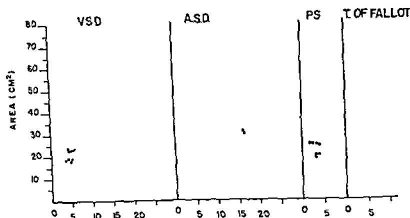


Fig 11 Correlation between the end d astol c area of the left atrium and the PBF (l/min) D rect relationsh p appears to be present in the four groups of congenital heart disease

may b related to diminution of the pulmonary blood flow according to prog gressive anatomic changes in the small pulmonary vessels (BROTMACHER & CAMPBELL 1958 LYNFIELD GASUL & LUAN 1959 NADAS 1960 and 1963 SOLOFF et coll 1956 STANTON & FYLLER 1961 WOOD MCDONALD & EMMA NUEL 1958 ADAMS 1957) The regression line of atrial septic defect appears almost superimposed upon the normal at all ages This indicates that the progressive increase in size of the chamber is due to the increase in bodyweight and height

Pulmonary stenosis and Fallot s tetrad have regression lines below the normal one This is as it should be for the left atrium should be small due to a low pulmonary flow in these anomalies It should also be noted that as the sur face area increases so does the distance between the normal regression line and those corresponding to pulmonary stenosis and Fallot s tetrad

The severity of the pulmonary stenosis increases with age (NADAS RUDOLPH & HOFFMAN 1960) If obstruction to the blood flow is greater as the patient grows the pulmonary flow will be lower the left atrial chamber should consequently be smaller An advantage in estimating the size of the left atrium in this manner is a relative correlation with the different hemodynamic para meters Comparison of the PFI (l/min/m²) with the area of the left atrium without any correction for BSA shows an inverse relationship between both parameters in pulmonary stenosis and Fallot s tetrad This is not acceptable

The parameter must be put in common terms when comparing the amount of blood flowing through the lesser circulation and the size of the left atrium This can be done by (1) plotting the area of the chamber without any correc

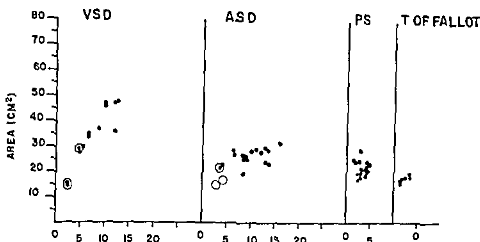


Fig 10 Correlation between PFI in l/min/m² and the end diastolic area of left atrium corrected for the BSA (cm²/m²)

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Values above the normal were recorded in 81 2 % of the cases of ventricular septal defect, 64 % of atrial septal defect, 17 % of pulmonary stenosis and 30 % of Fallot s tetrad It should be stressed that many observation points in the scatter diagram fall very close to the normal line, and evaluted by the classical roentgenographic method they would be considered as normal It is most important to point out that in both ventricular and atrial septal defects all cases in this investigation with high pulmonary resistance had values below normal *Large left to right shunts were associated with a large atrium* Cases with increased pulmonary vascular resistance and increased flow (NADAS 1960) were found to have areas that fell above the normal regression line They may be considered as an intermediate stage between cases with high pulmonary pressure associated with high flow (hyperkinetic pulmonary hypertension) and those with high pulmonary resistance and low pulmonary flow Estimation of the size of the left atrium in these conditions is very helpful in evaluating the hemodynamic characteristics

The regression line of normal cases compared to those of the group mentioned above illustrates certain points The fact that the regression line of ventricular septal defect lies above the normal indicates a larger atrial chamber It should be stressed that this regression line approaches the normal one as the BSA increases This means undoubtedly that as the subject advances in age, the chamber of the left atrium appears to become relatively smaller This finding

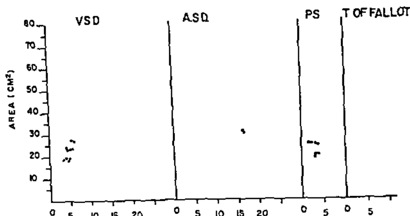


Fig 11 Correlation betwe n the end diastol c area of the left atrium and the PBF (l/m n) D rect relat onship app ars to be present in the four groups of congenital heart d ease

may be related to diminution of the pulmonary blood flow according to progressive anatomic changes in the small pulmonary vessels (BROTMACHER & CAMPBELL 1958 LYNFIELD GASUL & LUAN 1959 NADAS 1960 and 1963 SOLOFF et coll 1956 STANTON & FYLLER 1961 WOOD MCDONALD & EMMANUEL 1958 ADAMS 1957) The regression line of atrial septic defect appears almost superimposed upon the normal at all ages This indicates that the progressive increase in size of the chamber is due to the increase in bodyweight and height

Pulmonary stenosis and Fallot s tetrad have regression lines below the normal one This is as it should be for the left atrium should be small due to a low pulmonary flow in these anomalies It should also be noted that as the surface area increases so does the distance between the normal regression line and those corresponding to pulmonary stenosis and Fallot s tetrad

The severity of the pulmonary stenosis increases with age (NADAS RUDOLPH & HOFFMAN 1960) If obstruction to the blood flow is greater as the patient grows the pulmonary flow will be lower the left atrial chamber should consequently be smaller An advantage in estimating the size of the left atrium in this manner is a rel— c correlation with the different hemodynamic parameters Comparison of the PFI (l/min/m²) with the area of the left atrium without any correction for BSA shows an inverse relationship between both parameters in pulmonary stenosis and Fallot s tetrad This is not acceptable

The parameter must be put in common terms when comparing the amount of blood flowing through the lesser circulation and the size of the left atrium This can be done by (1) plotting the area of the chamber without any correc

tion against the PBF (l/min), and (2) plotting the area corrected for the BSA (cm^2/m^2) against PFI ($l/min/m^2$) These were followed by scatter diagrams (Figs 10 and 11) A direct relationship was evident in all the diagnostic groups This correlation should be taken as being capable of influencing the results the BSA (m^2) and the amount of blood running through the lesser circulation (ASD excluded) A direct relationship appears to be present in ventricular septal defect, pulmonary stenosis and Fallot s tetrad but none in atrial septal defect This finding means that the size of the left atrium remains within normal limits when the values are referred to one square meter, regardless of the importance of the flow

The defect of the septum is an escape valve which impedes the enlargement of the chamber whatever the magnitude of the left to right shunt These findings thus correspond with the pathologic characteristics of each of the groups studied

The reader is referred to ARVIDSSON s (1964) paper in which the volume of the left atrium was also measured at end diastole Correlations with different variables were made and similar conclusions drawn in cases of left to right shunts, pulmonary stenosis and aortic diseases

Conclusions

The end diastolic area of the left atrial chamber has been determined angio graphically in the anteroposterior projection in 10 normal cases and its results plotted against the body surface area (m^2) A regression line was obtained to predict the normal value for each BSA

The end diastolic area of the chamber was estimated in 32 cases of ventricular septal defect, 30 of atrial septal defect 21 of pulmonary stenosis and 17 cases of Fallot s tetrad Regression lines for all groups were determined

1 Comparison of the normal regression line with those of these groups of congenital heart disease according to body surface area of the patient has been discussed

2 Uncomplicated cases of ventricular septal defect were found to have values above the normal regression line Cases with high pulmonary resistance had areas that fell below the normal line and atrial septal defect a regression line almost superimposed upon the normal Pulmonary stenosis and Fallot s tetrad were found to have a regression line below the normal

3 This method permits correlations, not possible with others, between the size of the chamber and variables such as the pulmonary flow index ($l/min/m^2$) and pulmonary blood flow (l/min) etc The most reliable correlation appears to occur when the area of the left atrium, corrected for the BSA (cm^2/m) is plotted against the pulmonary flow index (l/min/m)

Acknowledgements

The authors are grateful to the Division of Biometry University of Miami School of Medicine for statistical assistance and for the support given by Research Grant HE 06514 of the National Institute of Health Department of Health Education and Welfare Public Health Service Bethesda by the Heart Association of Greater Miami Florida and by the Heart Asso iation of Broward County Florida

SUMMARY

The size of the left atrium has been estimated from its end diastolic area (cm^2) in the frontal projection The values in normals were plotted against the body surface area (m^2) Similar studies were performed in cases of congenital heart disease Regression studies were performed in cases of congenital disease Regression lines were obtained in all the cases and the values were correlated with the pulmonary flow index (l/min/m) and pulmonary blood flow (l/min)

ZUSAMMENFASSUNG

Die Gross des linken Vorhofe wurde am Ende der Diastole bei sagittalem Strahlengang in Quadratzentimetern bestimmt Die an normalen Personen erhaltenen Werte wurden zu der Gesamtkorperoberflache in Beziehung gesetzt Ähnliche Untersuchungen fanden an Fallen von angeborenen Herzfehlern statt Ein Abfall der Kurve wurde in allen Fallen fest gestellt und die Werte wurden mit dem Durchblutungsindex der Lunge (l/min/m) und mit der Lungendurchblutung (l/min) in Beziehung gesetzt

RÉSUMÉ

Le volume de l oreillette gauche a ete estimé a partir de sa surface telésystolique (en cm^2) en projection frontale Sa valeur chez des sujets normaux est rapportée a la surface cutanée (en m^2) Les memes m sures ont été faites dans des cas de cardiopathie congénitale Des étud s de régres ion ont été faites dans des cas de cardiopathie congénitale On a obtenu des lignes de régression dans tous les cas et on a calculé la corrélation avec l indice de débit pulmonaire (l/min/m) et avec l debit sanguin pulmonaire (l/min)

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FROM THE ROENTGENDIAGNOSTIC DEPARTMENT (DIRECTOR PROF F KNUTSSON)
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RELATIONSHIP BETWEEN CHOROID PLEXUS OF EYEBALL AND CAROTID SIPHON

by

KJELL BERGSTROM and HERMAN LODIN

The position of the eyeball in the orbit may be determined by different roentgenologic methods In isolated cases the posterior part of the eyeball may be demarcated from the orbital adipose tissue by tomography but the method cannot be used as a routine By intraorbital injection of gas or water soluble contrast media on the other hand the outlines of the eyeball can be clearly defined but the injection may possibly influence its position By carotid angiography contrast filling of the choroid plexus of the eyeball can generally be achieved especially on injection into the internal carotid artery The posterior margin of the eyeball and consequently the position of the eyeball can then be established (SCHURR 1951)

DECKER 1955) DECKER & SCHLEGEL (1957) YASARGIL (1957) KRAYENBUHL 1962) DILENGE FISCHGOLD & DAVID (1961) DI CHIRO (1961) WHEELER & BAKER (1964) and DE RAAD (1964) have described the normal anatomy as seen at orbital angiography and have demonstrated the value of this examination in different intra and peri orbital pathologic processes

Exophthalmus occurs on anterior displacement of the eyeball This may be

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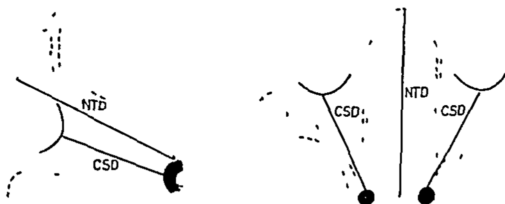


Fig 1 Schematic illustration of distances measured from the lateral angiogram only (left) and relationships with distances in the axial projection (right) CSD = distance between the choroid plexus and carotid siphon NTD = distance between the nasion and tuberculum sellae

unilateral or bilateral and is caused by intraorbital or peri orbital expansive processes and certain aneurysmal changes, it may also arise in endocrine disturbances The protrusion of the eyeball is evaluated by means of exophthalmometry, usually by the Hertel method, whereby the corneal vertex is measured in relation to the lateral orbital margin This gives only relative values on the degree of exophthalmus, i e the difference between the two corneal peaks or the difference between measurements on different occasions in one and the same subject, no absolute measure of the position of the eyeball within the orbit is obtained

No determination of the fronto occipital position of the eyeball in relation to a fixed point, i e evaluation of any degree of displacement, has been reported by the authors mentioned above It was therefore considered important to make an attempt to determine the normal fronto occipital position of the eyeball in the orbit by means of carotid angiography A small series of exophthalmic patients were compared with a normal series

Material A total number of 194 angiographic examinations were performed in 151 patients of ages ranging between 12 and 80 years, 138 of whom had no exophthalmus or other orbital disorder Left side angiography was performed in 104, right side in 90, and bilateral angiography in 39 patients In the 13 patients who had exophthalmus, bilateral in one it had been produced by intraorbital tumours arteriovenous aneurysms, inflammatory conditions or thyrotoxicosis They had all undergone exophthalmometry by the Hertel method A difference of ~ 3 mm between the right and left eye was regarded as a positive value, if the difference was less the value was regarded insignificant

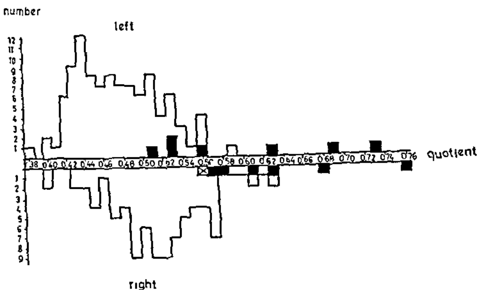


Fig 2 D tribution of the quot ent CSD/NTD in normal patients (unfilled columns) in exophthalmic patients with positive Hertel (black columns) and in exophthalmic patients with insign fi ca t Hertel value (x)

Examination technique Carotid angiography was performed by the injection of Urografin 60 % into the internal carotid or common carotid artery The tube was centered 2 to 3 finger breadths above the external auditory meatus All investigations were performed with the left side in direct contact with the film changer FFD being constant

Measurement technique The anterior vertex of the carotid siphon the nasion and the tuberculum sellae were used as fixing points Two distances were measured in the lateral angiogram (Fig 1) (1) the shortest distance between the choroid plexus and the carotid siphon or the CSD (choroid siphon distance) and (2) the distance between the nasion and the tuberculum sellae or the NTD (nasion tuberculum distance)

The carotid siphon was used as a reference point to the choroid plexus since this is the only practical one near the sagittal plane through the eye ball and since the axis CSD forms a smaller angle with the sagittal plane than that which would have been obtained if a structure in the midline e g tuberculum sellae) had been chosen This means less influence on the distance to the eyeball on slight rotation of the head around its vertical axis and is of special importance when comparing the right and left sides The

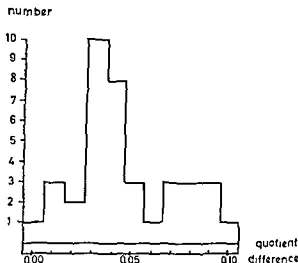


Fig 3 Differences between quotients CSD/NTD on right and left sides in 38 normal subjects bilaterally examined In comparison with the left side the quotient on the right side was greater in 37 subjects and the same in one

anterior vertex of the carotid siphon has been found to vary in position in a negligible degree on comparison between the two sides, the difference did not exceed 2 mm in the 39 patients examined bilaterally

NTD is a fixed distance, and small degrees of skull rotation produce negligible changes as its axis *coincides with the midline*

CSD was correlated to NTD (expressed as the quotient CSD/NTD), thus compensating for variations in skull length and any difference in the degree of enlargement at different examinations This quotient is used as an expression of the position of the eyeball in the orbit

Only those angiographies in which the rotation of the head was of such a small degree that the difference between the mandibular joints did not exceed 10 mm in the roentgenogram were accepted for evaluation The highest possible quotient difference, on a repeated ipsilateral examination, will thus be about 0 02 Bilaterally, the quotient difference under ideal conditions (without head rotation) will be about 0 03, which on rotation may rise to as high a figure as 0 06 however

Results and Discussion

The distribution of the quotients for both normal and exophthalmic patients is given in Fig 2

Bilateral examinations were performed in 38 normal patients, the quotient differences between the right and left sides are given in Fig 3

In one patient, with unilateral exophthalmus (right side) angiography was also performed on the normal side The quotient difference was found to be 0 16

In 6 normal patients repeat examinations of the same side were performed, and the quotient differences between the respective examinations were between 0 01 and 0 03

Normal cases As apparent from Fig 3 the quotients for the right side were greater than for the left (in one instance they were equal) The same tendency is evident in Fig 2 This may be explained by the fact that the degree of enlargement was greater for the right than for the left side, since the investigations were performed with the left side in contact with the film changer and the CSD line for the two sides deviated in opposite directions from the sagittal plane (Fig 1 right) The mathematically predicted quotient difference with no or only negligible rotation is about 0 03 but may be as high as about 0 06 The quotient difference in a number of the normal patients was greater than 0 06 however with a maximum of 0 10 (Fig 3) There were thus normal cases with unexpectedly high quotient differences that could not be explained solely by projection differences nor could they have been due to technical factors in the mensuration since all measurement points were well defined and easily distinguishable It is most probable that these high quotient differences were caused by asymmetries within the cranium

Fig 2 reveals that in about 75 % (74 out of 97) of the normal cases examined on the left side the quotient CSD/NTD was < 0 51 and in about 80 % (69 of 83) of the normal cases examined on the right side it was < 0 56

Exophthalmic patients A certain degree of overlapping between normal and exophthalmic cases may be expected and in the present series this was particularly notable for the left side (Fig 2) The exophthalmic series included a number of mild conditions (e g one patient with an insignificant Hertel value) and these also had the lowest quotients In the one unilaterally exophthalmic patient in whom angiography was performed on the normal side the quotient difference was 0 16 while in normal cases this difference did not exceed 0 10

Conclusion

Fig 2 indicates that the material presented may as far as the CSD/NTD quotient is concerned be divided into three groups (1) left side quotient < 0 51 right side quotient < 0 56 normal patients only (2) left side quotient 0 51—0 59 right side quotient 0 56—0 63 normal patients and those with mild exophthalmus (3) left side quotient > 0 60 right side quotient > 0 64 exophthalmic patients only

SUMMARY

An angiographic method of determining the absolute fronto-occipital position of the eyeball, based on the quotient of the distances between the choroid plexus and the siphon on the one hand and between the nasion and the tuberculum sellae on the other hand is described.

ZUSAMMENFASSUNG

Beschreibung einer neuen Methode um bei Angiographie die absolute fronto-occipitale Lage des Augapfels mit Hilfe des Quotienten der Abstände des *Plexus chorioideus* bis Carotissiphon und der Nasion bis Tuberculum sellae zu bestimmen.

RÉSUMÉ

Description d'une méthode angiographique de détermination de la situation absolue du globe oculaire dans le sens fronto-occipital basée sur le quotient des distances entre le plexus choroïde de l'oeil et le siphon carotidien d'une part et entre le nasion et le tubercule de la selle d'autre part.

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EFFECT OF ANGIOCARDIOGRAPHY ON ERYTHROCYTE AGGREGATION IN THE CONJUNCTIVAL VESSELS

by

Lars Bjork

Increased intravascular aggregation in the conjunctival vessels has been observed in patients after injection of various contrast media (SOBIN et coll 1959 LINDGREN LOFSTROM & SALTZMAN 1964 inter alios) No studies have been performed on the erythrocyte aggregation after injection of large doses of contrast media however as in angiocardiography The present investigation was undertaken to demonstrate the frequency and severity of changes in the aggregation of red blood cells after angiocardiography with the two contrast media most currently in use Isopaque 60 % and Urografin 76 %

Material and Methods Forty two unselected patients were studied 26 men and 16 women in whom angiocardiography had been performed as part of a routine preoperative evaluation of cardiac disease the ages varied from 18 to 60 years

Urografin 76 % (sodium and methylglucamine diatrizoate) was used in half the number of patients and Isopaque 60 % (sodium metrizoate) in the other half There were no methodologic differences between the two groups as to

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Photomicrogram of conjunctival vessels after angiocardiography demonstrating granulation in the small and large vessel and segmentation of the small vessel

dose of contrast medium, number or site of injections The total dose varied from 0 8 to 3 1 ml/kg bodyweight and the number of injections from one to five The speed of injections was approximately 35 ml/min All injections were made into the left side of the heart or into the aorta

The blood vessels of the bulbar conjunctiva were studied with a corneal microscope, and photomicrograms of three different areas were obtained immediately before injection of the contrast medium, and then at 5, 15 and 60 minutes and 24 hrs after the last injection Additional photomicrograms were obtained in the first ten patients, at approximately 2 min intervals, during the first 20 minutes after the injection of the medium The first films could with the technique used be obtained within 1 to 2 min after the last injection

The degree of aggregation in the conjunctival vessels was evaluated on the photomicrograms (see accompanying figure) and was classified as one of the following types

0 no visible granulation
\+ granulation in small vessels
\+\+ segmentation of small vessels
\+\+\+ granulation in and occasional segmentation of larger vessels

Table

Conjunctival sludge before and after angiocardiography

	Before angiocardiography					Changes after angiocardiography			
	No of patients	0	+	++	+++	Increase +	Increase ++	Decrease	No difference
Urografin 76	21	8	9	4	—	8	3	1	9
Isopaque 60	21	7	8	5	1	7	2	1	11
Total	42	15	17	9	1	15	5	2	20

Results

Two thirds of the patients had aggregation in the conjunctival vessels before the angiocardiography (see Table). Fifteen minutes after angiocardiography the sludge increased in 20 patients, in another 20 there was no difference and in two patients a decrease in aggregation was observed (see Table). In 75 % of the patients the increase in aggregation was one step of the scale and only in 25 % was a two step increase recorded.

Changes in the degree of aggregation were never present earlier than 5 min after the injection of contrast medium and in most instances no changes appeared until 15 min after the injection.

When a change in the degree of sludge had occurred it remained the same during the 60 min observation period in all the patients. A decrease in sludge was evident in 13 patients and an increase in two patients at 24 hours whereas the degree of aggregation remained unchanged in the others.

The changes in the degree of sludge after injection of Urografin 76 % were not strikingly different from those after the injection of Isopaque 60 % (see Table). There was no correlation between the changes in sludge and the amount of contrast medium or number of injections. A decrease in the hematocrit value varying from 10 % to 33 % was present after angiocardiography in all the patients. The degree of hemodilution seemed not to be related to the changes that were observed in the intravascular aggregation. Moderate and transient changes in heart rate and blood pressure occurred in nearly all the patients after angiocardiography; these changes were no more frequent or severe in patients with increased sludge after angiocardiography than in the others.

Discussion

The classification of the degree of aggregation in the conjunctival vessels is of course subjective and borderline cases of difficult classification were encoun

tered The use of photomicrograms permitted independent evaluation of the sludge *without* knowledge of clinical and other facts about the patients

Variations in the degree of aggregation in different parts of the bulbar conjunctiva may occur In an attempt to minimize this source of error three photomicrograms of three different areas of the conjunctiva were obtained at every observation The degree of sludge was usually similar in these three films, but in three patients one revealed no granulation (0) whereas the other two had granulation in the small vessels (+) These patients were grouped as 'plus patients A little less than half the number of the patients in this investigation had an increase in aggregation after the injection of contrast medium

SOBIN et coll reported increased conjunctival sludge in 20 of 24 patients after intravenous injection of 30 ml Hypaque 50 % or Miokon 50 % although *in similar experiments* LINDGREN *et coll found increased aggregation only in* four of 25 patients after injection of Urografin The diverging results are difficult to explain but there were differences in the observation technique, the amount of contrast medium used and injection of the technique however In the present investigation however the dose of contrast medium seemed to be unrelated to the changes in the intravascular aggregation

SOBIN et coll and LINDGREN et coll reported the changes in aggregation as occurring immediately after injection of the medium and disappearing within 10 to 20 minutes These findings are different from the present ones, in which no change was evident earlier than 5 min after the injection and the maximum changes after approximately 15 min, the changes persisted for at least 60 min and were sometimes still present 24 hours after the injection These different reports may be explained by a more marked and rapid hemodilution occurring after the rapid aortic or intracardiac injections of large doses than after comparatively slow intravenous injections of smaller doses of contrast medium The hemodilution reaches a maximum within one minute and has largely disappeared after between 15 and 30 min (BJORK) It seems possible that the dilution may be sufficiently large to prevent increased sludging during the first 5 to 15 min after angiocardiography There was, on the other hand, no clear correlation between the changes in aggregation and the degree of hemodilution measured by the decrease in hematocrit The increase in aggregation that remained after 60 min and in a third of the patients after 24 hours, indicates a more profound disturbance in the aggregation mechanism in these patients than in those studied by SOBIN et coll and LINDGREN et coll Again, the higher doses of contrast medium and the higher speed of injection in the present investigation may explain the difference

Since an increase in intravascular aggregation was evident in only a little less than half the material, the laboratory and clinical findings, in the patients

with and in the patients without increased aggregation after angiocardiography, were compared No obvious differences between the two groups was apparent Normal and elevated blood sedimentation rates were equally frequent in the two groups No obvious correlation existed between the changes in sludge and side effects (sensation of heat headache) felt by the patients It is interesting to note that the changes in sludge occurred only after several minutes when the side effects had usually disappeared

As many as two-thirds of the patients had some degree of aggregation in the conjunctival vessels before angiocardiography This high incidence of aggregation could possibly have been caused by stress during catheterization which always preceded the angiocardiographic studies Eleven patients were studied with this in view Photomicrograms of the conjunctival vessels were obtained the day before catheterization was to take place immediately before starting the catheterization procedure at the end of it immediately before angiocardiography and 15 min after angiocardiography An increase in intravascular aggregation occurred in four patients after the catheterization procedure while there was no difference in the remaining seven patients An increase in intravascular aggregation was evident in five patients after angio cardiography This indicates that the catheterization procedure itself may produce increased intravascular aggregation in cardiac patients However the procedure is not the only, and probably not even the most important cause of the pre injection increase in intravascular aggregation in these pa tients

Many of the factors responsible for the increase in intravascular aggrega tion after angiocardiography still remain unknown In view of the findings by LASSER et coll (1962) a detailed study of the plasma proteins before and after angiocardiography may be expected to offer further explanation of the mechanism that leads to increased sludge in one patient but not in the other

SUMMARY

An in rease in erythrocyte aggregation in the conjunctival vessels occurred after angiocardio-graphy in 20 of 42 patients The increase was equally frequent with the two contrast media used (Urografin 76 Isopaque 60) and bore no obvious correlation to other clinical or laboratory fir d ngs

ZUSAMMENFASSUNG

Bei einem Material von 42 Patienten zeigten 20 Falle eine Aggregation von Erythrozyten in den Konjunktivalgefassen nach Angiokardiographie D eses Phenomen war gleich haufig bei den beiden benutzten Kontrastmitteln (Urografin 76 ° Isopaque 60) Kein Zusammen hang mit anderen klinischen oder Laborbefunden konnte festgestellt v erden

tered The use of photomicrograms permitted independent evaluation the sludge without knowledge of clinical and other facts about the patien

Variations in the degree of aggregation in different parts of the bulb conjunctiva may occur In an attempt to minimize this source of error th photomicrograms of three different areas of the conjunctiva were obtained every observation The degree of sludge was usually similar in these three film but in three patients one revealed no granulation (0) whereas the other t had granulation in the small vessels (+) *These patients were grouped as 'pl* patients A little less than half the number of the patients in this investigati had an increase in aggregation after the injection of contrast medium

SOBIN et coll reported increased conjunctival sludge in 20 of 24 patien after intravenous injection of 30 ml Hypaque 50 % or Miokon 50 % althou in similar experiments LINDGREN et coll found increased aggregation only four of 25 patients after injection of Urografin The diverging results are dif cult to explain but there were differences in the observation techniqu the amount of contrast medium used and injection of the technique howev In the present investigation however the dose of contrast medium seemed be unrelated to the changes in the intravascular aggregation

SOBIN et coll and LINDGREN *et coll reported the changes in aggregation* occurring immediately after injection of the medium and disappearing with 10 to 20 minutes These findings are different from the present ones, in whic no change was evident earlier than 5 min after the injection and the maximu changes after approximately 15 min, the changes persisted for at least 60 m and were sometimes still present 24 hours after the injection These differe reports may be explained by a more marked and rapid hemodilution occurrin after the rapid aortic or intracardiac injections of large doses than after com paratively slow intravenous injections of smaller doses of contrast medium The hemodilution reaches a maximum within one minute and has large disappeared after between 15 and 30 min (BJORK) It seems possible that th dilution may be sufficiently large to prevent increased sludging during th first 5 to 15 min after angiocardiography There was, on the other hand, n clear correlation between the changes in aggregation and the degree of hemod lution measured by *the decrease in hematocrit* The *increase in* aggregatio that remained after 60 min and in a third of the patients after 24 hours indicates a more profound disturbance in the aggregation mechanism i these patients than in those studied by SOBIN et coll and LINDGREN et coll Again, the higher doses of contrast medium and the higher speed of injectio in the present investigation may explain the difference

Since an increase in intravascular aggregation was evident in *only* a littl

FROM THE RADIOLOGIC CLINIC (DIRECTOR PROF J HOLY) AND SURGICAL CLINIC I (DIRECTOR PROF J UHLÍR), BRNO CZECHOSLOVAKIA

ISOTOPE ARTERIOGRAPHY IN OBLITERATIVE ARTERIAL DISEASE OF THE LOWER EXTREMITIES

by

J VITEK I ZAVREL A HUVAR, Z KASPAR and M KONECNY

The intraarterial injection of an isotope before arteriography or aortography has been described in the literature as a means of determining the most suitable moment for obtaining roentgen films (SCHUMACHER & WITT 1964) Isotopes have also been employed for studying the arterial flow through calf and foot both in normal cases and in atherosclerosis and for the measurement of the retardation of flow in obliterative disease (WAGER 1961 CUYPERS 1964)

We have tried to find out whether painless arteriography with a small amount of isotope may be used for determining the presence of an occlusion and for localizing it with a satisfactory degree of accuracy If this were possible, we would have a method acceptable to the patient and of great value particularly in control examinations following vascular surgery with a view to establish if the operation has been successful It would also be useful for demonstrating the functional aspects of the blood supply of a lower limb, much better than arteriography because the injection of 20 to 40 ml of contrast medium into the arterial bed almost certainly affects the hemodynamics

Submitted for publication 20 December 1965

RÉSUMÉ

Chez 20 malades sur une série de 42, l angiocardiographie a été suivie d une augmentation de l agrégation des érythrocytes dans les vaisseaux conjonctivaux Cette augmentation a été aussi fréquente avec les deux moyens de contraste utilisés (Urografin 76 % Isopaque 60 %) et n a pas présenté de corrélation évidente avec d autres anomalies cliniques ou biologiques

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Fig 2 Arrangement of probes during measurement

iodine The injection was performed with an ordinary No 24 needle against the blood flow in order to eliminate the direct application of the solution into the deep femoral artery With 2 ml of the solution the injection is practically instantaneous so that the measurement takes place simultaneously The plunger of the syringe ought thereafter to be withdrawn to ensure that all the medium has been injected into the artery

Our measurement was carried out by means of a Duovigraph ACEC with two detector probes (Fig 2) One of the probes was placed above the femoral artery at the middle of the thigh and was medially inclined this in an attempt to prevent measurement of collateral flow from the deep femoral artery The other probe was fixed above the presumed site of ramification of the popliteal artery i e at the level of the tibial tuberosities

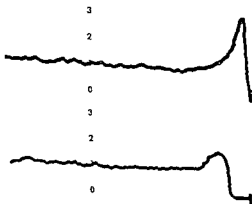


Fig 3 Characteristic curves when the arteries are patent

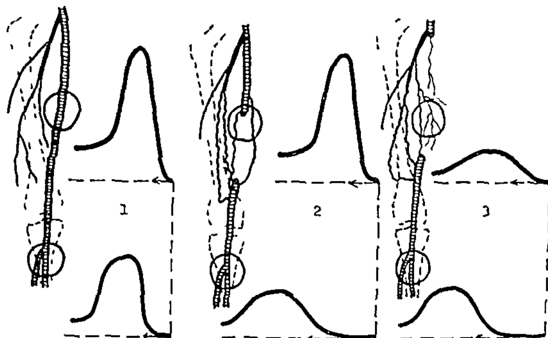


Fig. 1. Schematic illustration of expected types of curves: in arterial patency (1), in occlusion of the femoral artery behind the femoral detector probe (2), and in occlusion of the femoral artery in front of the femoral probe (3).

Last but not least, the technique should enable the demonstration of the effect of sympathectomy in an objective and exact manner.

Since curve registration is effectuated with two detector probes, one (femoral) placed in the central part of the thigh and the other (crural) at the site of the ramification of the popliteal artery, the curves obtained may be expected to display the following features: (1) instantaneous rise and fall of radioactivity in both probes when the main arteries are normally patent, (2) quick and instantaneous rise in the femoral probe, and delayed and slower rise in the crural probe, when occlusion of the femoral artery is present behind the femoral probe, (3) a small rise in activity of the registered collateral circulation in the femoral probe, and a delayed and slower rise in the crural probe, when the femoral artery is occluded in front of the femoral probe, the assumption being that the collateral flow via the deep femoral artery will not be registered to any great extent (see Fig. 1).

Method. We used ^{131}I labelled serum albumin, hippuran ^{131}I, and Na ^{131}I, with a radioactivity of about 20 microcuries, diluted in 2 ml normal saline; this small dose of radioactivity is entirely harmless. Each patient who had not undergone arteriography before the examination was treated with 30 drops of Lugol solution for two successive days so as to saturate *the thyroid* with

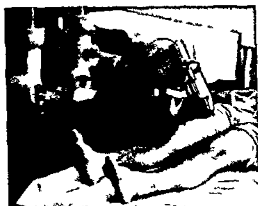


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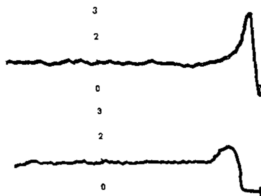


Fig 3 Characteristic curves when the arteries are patent

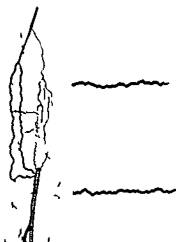


Fig 4 Slow rise of radioactivity in the femoral probe in a case of occlusion of the femoral artery

The following values were used for the measurements
ments 3 10⁴ or 10⁵ imp/min, inertia time constants 0 03
paper feed 30 cm/min, analyser window width 25 V Th
proved to be the best range of measurement 3 10⁴ imp
constant 0 3 sec, speed of paper feed 30 cm/min

The following values were evaluated from the curves

1 'Delay', i e time elapsed from isotope injection to sta

2 Steepness of rise of curve, i e time elapsed from start
curve

3 Character and breadth of curve peak

4 Character of descending curve and fall interval

5 'Residual continued radioactivity', as shown by the he

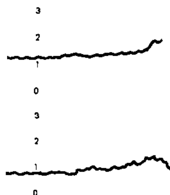


Fig 5 Usual curve pattern when the femoral artery is occluded

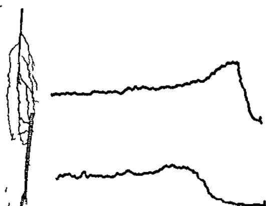


Fig 6 Slow fall in activity and high residual activity in the femoral probe when the femoral artery is occluded (group 1)

above the abscissa after the initial quick fall (given as percentage of length of curve)

6 Relationship between the values of the radioactivity in thigh and lower leg established as percentage of the height of the femoral curve

The absolute height of the curve has not been taken into the account since this is dependent on a series of factors such as the parameters of measurement degree of dilution of the isotope and tissue width the constancy of which cannot be guaranteed

Results

1 *If the main arterial stems are patent* the findings correspond to the theoretical assumption (see Fig 3) The femoral probe then indicates an instantaneous steep rise and a quick fall in radioactivity The crural probe records only a small delay (1 sec) and again a steep rise (about 2 sec) The peak breadth is then larger and the fall slower these facts are determined first by the radio activity from the branches of the main arterial stems as well as from the venous back flow and secondly by the further dilution of the isotope The residual activity both in the thigh and the lower leg is high and its fall is slow

2 *When the femoral artery is occluded* Only in one case was there evidence of the curve expected for the occlusion in the proximal part of the femoral artery i e in front of the femoral probe (Fig 4) Its characteristic feature consisted in a slow rise of radioactivity although this reached a considerable height This occurred in a case in which the whole femoral artery was occluded

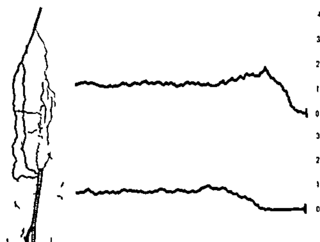


Fig. 4 Slow rise of radioactivity in the femoral probe in a case of occlusion of the femoral artery

The following values were used for the measurements: range of measurements 3 10^4 or 10^5 imp/min, inertia time constants 0.03 or 0.3 sec, speed of paper feed 30 cm/min, analyser window width 25 V. The following values proved to be the best: range of measurement 3 10^4 imp/min, inertia time constant 0.3 sec, speed of paper feed 30 cm/min.

The following values were evaluated from the curves:

1. 'Delay', i.e. time elapsed from isotope injection to start of rise in curve.
2. Steepness of rise of curve, i.e. time elapsed from start of rise to peak of curve.
3. Character and breadth of curve peak.
4. Character of descending curve and fall interval.
5. 'Residual continued radioactivity', as shown by the height of the curve

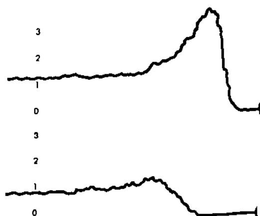


Fig. 5 Usual curve pattern when the femoral artery is occluded

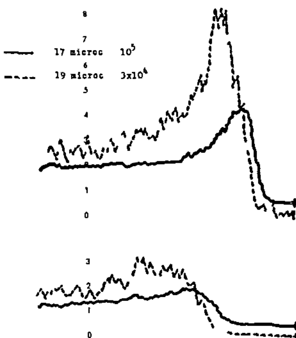


Fig 9 Isotope arteriography before and after sympathectomy (dashed curve) The circulation grew worse after sympathectomy Only the patterns of the respective curves can be compared not the amplitudes since in the examination after lumbar sympathectomy a higher radioactivity and a different range of measurements were used

This pattern seems to be characteristic of the break down of the radioactive bolus in the collateral blood bed and accordingly of a partial or complete occlusion in the femoral artery

As to the character of the descending part the curves may be divided into two group The curves of the first group descend surprisingly slowly and the radioactivity in the thigh continues to be high (Fig 6) The curves of the second group have a steeper fall (Fig 7) The character of the descending part of the curve thus points to the state of the collateral blood circulation in the thigh and to the degree of its emptying into the peripheral branches It seems reasonable to suppose that the respective occlusions in front of and behind the femoral probe may in this way be distinguished An occlusion behind the probe may be assumed to cause a quicker fall while an occlusion in front of the probe may be expected to result in a slower fall and a high residual radioactivity In the latter event the region of the detector probe is supplied with blood coming from a dense collateral network and this together with a quick venous back flow creates a slowly vanishing depot of the isotope The respective groups will differ in quantity only and the differences are often relatively small

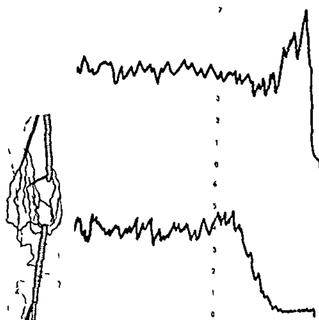


Fig 7 Quick fall in radioactivity in the femoral probe when the femoral artery is occluded (group 2)

the larger collateral stems ran along only the lateral aspect of the thigh (See drawing in Fig 4) In all the other cases, the femoral detector probe recorded a rather quick and steep rise in radioactivity, 2 to 3 sec (Fig 5), even if the cases presented evidence of occlusion in front of the femoral probe This fact seems to indicate that even when the femoral probe is inclined inwardly, it always measures the larger part of the collateral blood flow that *speedily supplies the region of the probe with blood and thus imitates the patency* of the femoral artery

The curve peak was however always wider and rugged, and the fall was slow

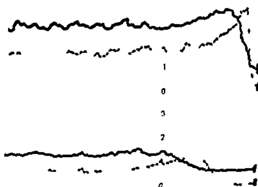


Fig 8 Isotope arteriography before and after sympathectomy (dashed curve) Marked improvement of the circulation after sympathectomy

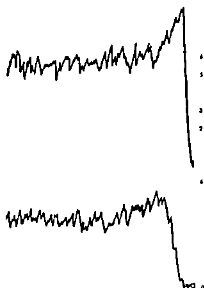


Fig 11 Occlu on of the d tal anastomosis of femo ropopliteal by pass graft Rapid r se in radioact ity in the crural probe

Conclusions

The results obtained in clinical pra tice seem to indicate that the technique of isotope arteriography has so far been successful Partial or complete occlusion of the femoral and popliteal arteries or of an arterial prothesis may be deter mined and the character of the collateral circulation revealed in cases of obliterative arterial di ease of the lower extremities The site of the occlusion cannot be localized with certainty however The diagnosis is possible solely from the recordings of the femoral probe

The hemodynamics of the extremity are made evident by the method which furthermore accurately indicates changes taking place in the blood flow after lumbar sympathectomy and vascular surgery

Measurement of the radioactivity seems to be most suitably performed by means of several detector probes When two probes are used their best situa tions are at the middle of the thigh and on the foot a determination of the character of the peripheral blood supply is then assured

SUMMARY

Th t chniqu of isoto a terio͜graphy is described and its results in obliterative arterial d sease of the lo er extremity are evaluated The proc dure makes it possible to determine partial or complete occlusion of the femoral and popliteal arteries or of an arterial prosth sis and to demonstrate characteristic features of the collateral circulation



Fig. 10. Occlusion of femoral artery 15 years after femoral endarterectomy. Clinical improvement

Rather marked delay (2 to 10 sec), a slow rise in radioactivity (2 to 7 sec), as well as wide peak and a slow fall in the crural detector probe were recorded in each one of the above cases. This could be expected because the lower leg is supplied only from collateral arteries.

Nothing can be stated, with the above arrangement of probes, about the condition of the peripheral circulatory bed. A third probe would be suitable to measure the radioactivity in the periphery but since we have had no such probe at our disposal the second probe has, with good results, been placed in the region of the foot instead of near the tibial tuberosities.

3. *After lumbar sympathectomy*, with good clinical result, the isotope arteriography indicated an improvement in the blood supply to the lower extremity. A marked difference is apparent in Fig. 8. Each time interval grew *shorter*, and a better emptying of the collateral bed in the thigh took place. (The dashed curve indicates the state after lumbar sympathectomy.) After lumbar sympathectomy, with no clinical improvement of the blood supply in the extremity, each time value grew longer, although the curve had the same pattern (Fig. 9). In this case the lower extremity had later to be amputated.

4. *After reconstructive vascular surgery*, isotope arteriography clearly indicates the occlusion even when the clinical condition is satisfactory (see Fig. 10, a case examined 15 years after femoral endarterectomy). If the probes are placed on the thigh and the proximal part of the lower leg the pattern ought to be evaluated very carefully when a distal anastomosis of the femoropopliteal by-pass graft is occluded. The quick rise in radioactivity in the crural probe may be due to isotope accumulation in the by-pass graft, which in other respects is patent (Fig. 11).

FROM THE DEPARTMENT OF NEURORADIOLOGY (DIRECTOR PROF T GREITZ),
KAROLINSKA SJUKHUSET, STOCKHOLM SWEDEN

THE VASCULAR SUPPLY OF CHROMOPHOBE ADENOMAS

by

GUNNAR WESTBERG and RONALD J ROSS

The diagnosis of intrasellar and suprasellar lesions is usually made by roentgen examination of the skull and encephalography Encephalography is the most important procedure for delineation of the suprasellar extension of the tumour Angiography has apparently only occasionally been performed and mainly to exclude arterial aneurysms and to obtain information about the gross vascular anatomy Attention has been focused on the various type of displacement of the major vessels as being of aid in the differential diagnosis of suprasellar and sellar lesions (CHASE & TAVERAS 1961) The angiographic demonstration of tumour vessels in various pituitary growths has recently been reported (KIRCHEFF 1964 FEIRING & SHAPIRO 1964 DORAN & SCHWARTZ 1965 These authors mentioned increased vascularity in a few cases and put stress on the presence of tumour stain In two of the three cases described by DORAN & SCHWARTZ hypervascularity was demonstrated after radiotherapy of the pituitary area Other authors have described increased vascularity and tumour stain in pituitary growths but not all cases have been histologically confirmed

The present study is based on carotid angiographic examinations performed

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ZUSAMMENFASSUNG

Die Technik der Arteriographie mit Isotopen wird beschrieben und deren diagnostischer Wert bei arteriellen Verschlusskrankheiten des Beines erörtert. Die Methode erlaubt partielle oder vollkommene Verschlüsse der Femoralarterie oder der Poplitealarterie zu beurteilen und ebenfalls den Effekt von Einpflanzungen künstlicher Arterien und die typischen Eigenschaften einer kollateralen Zirkulation zu studieren.

RÉSUMÉ

Les auteurs décrivent la technique de l'artériographie isotopique et examinent l'intérêt de ses résultats dans les affections artérielles oblitérantes du membre inférieur. Cette technique permet de déceler les obstructions partielles ou complètes des artères fémorale et poplitée ou d'une prothèse artérielle, et montre les caractères de la circulation collatérale.

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Fig 2 Chromophobe denoma Tumour essels start to br nch near their orig n from the xtrada al pa t of the ca otid siphon



F g 3 Chr m ph b ad noma a) En phalography The supra ellar extension of the tumour d l eat d by air b) Car tid a giogr phy subtraction te hn que A fin net of t mou es ls co ers the tumou

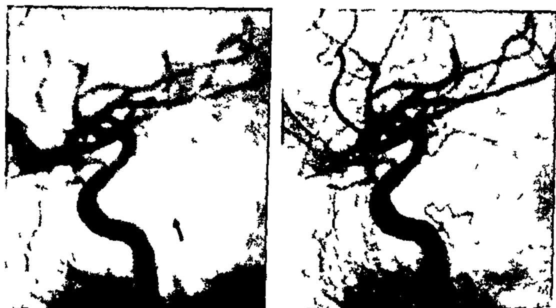


Fig. 1. Chromophobe adenoma. An enlarged and tortuous vessel arises from the extradural part of the *carotid siphon*.

in 31 cases of chromophobe adenomas. All cases were surgically treated and histologically verified; none had received radiotherapy before the roentgen examination. The cases were examined with rapid serial angiography and subtraction was usually performed.

A definitely increased vascular supply to the chromophobe adenoma was evident in five cases, and small vessels supplying the tumour were demonstrated in six. In the remaining twenty cases, no vessels in the tumour area were delineated, or the vessels were so small that they were not considered to be related to the tumour. Tumour vessels, when present, were readily demonstrated in lateral projection in the arterial phase. These vessels arose from the extradural portion of the carotid siphon and corresponded to those described in detail by SCHNURER & STATTIN (1963) in tentorium meningiomas and by WESTBERG (1963) in trigeminal neurinomas.

Variations in the appearance of the dilated vessels were evident. Either an enlarged and tortuous vessel, usually passing posteriorly and upwards (Fig. 1), was present, or the arteries started to branch near their origin (Fig. 2). In one case, a fine net of vessels covered the suprasellar portion of the tumour (Fig. 3). Bilateral carotid angiography was performed in three cases. In one of these cases the tumour was equally supplied from both carotid arteries (Fig. 4, a and b). In another case with increased vascularity the tumour was supplied by the right carotid artery alone. If left carotid angiography alone

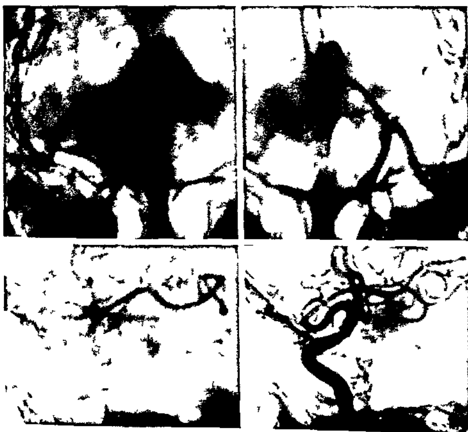


Fig 6 Intr and sup ellar meningioma The tumou s rich n vessels a is ng f om the extr dur l pa t f th ca tid s phon

case (Fig 5) were the small pathologic vessel better seen in a p than in lateral projection

An absolute correlation was established when the surgical and pathologic findings with respect to the vascularity of the tumour were compared with the roentgen findings In some cases in which no pathological vessels had been present on angiography the surgeon noted a hypervascular tumour In most cases in which hypervascularity was evident at angiography however the surgeon described the capsule as easily bleeding No tumours were reported malign nt

The investigation would therefore appear to indicate that the vessels are capsular rather than parenchymal Contrary to previous reports the present authors have not encountered a tumour stain of the kind seen in meningiomas



Fig 4a



Fig 4b

Fig 4 Chromophobe adenomas The tumour is equally fed from the left (a) and right (b) carotid siphon

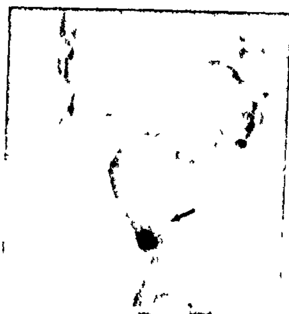


Fig 5

Fig 5 Small tumour vessels are evident in the a p view

had been performed in this case, the tumour vessel could not have been demonstrated The frontal view was difficult to evaluate because of the super imposition of subfrontal vessels and medial branches from the ophthalmic artery, a true a p projection through the orbits was therefore considered preferable for the frontal demonstration of the tumour vessels In only one

FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR PROF F KNUTSSON) UNIVERSITY HOSPITAL UPPSALA SWEDEN

MITRAL DOME FORMATION IN AORTIC VALVULAR DISEASES

by

KJELL BERGSTROM and HERMAN LODIN

BJORK & LODIN (1960) have stated that there would appear to be no indication for left ventricular angiocardiography in the *evaluation of the* mitral stenotic component of valvular lesions However, these authors observed a clearly outlined contrast free area at the site of the mitral orifice in diastole in certain of the left ventricular angiocardiograms This roentgenologic appearance was correlated to clinical observations and findings at operation The results may be summarized as follows No mitral dome was observed in cases where clinical signs of mitral stenosis were absent and mitral stenosis was found at operation in all the twenty operated cases in *which a dome* had previously been observed in all but one of these cases the mitral stenosis was advanced The contrast free area was due to fused mitral cusps which caused a domelike protrusion into the ventricular contrast accumulation Certain criteria were used *in* defining dome formation The dome should be observable in both the frontal and lateral planes and its whole circumference should be clearly outlined in the frontal plane BJORK & LODIN made the reservation however that if the ventricle were greatly enlarged, mitral *stenosis* might be present

Submitted for publication 16 February 1966

Furthermore, the vessels in the chromophobe adenomas were not as extensive as in meningiomas located in the same area (Fig. 6).

The carotid angiograms of 10 cases of craniopharyngeomas were also examined in an attempt to evaluate the appearances of tumour vessels in chromophobe adenomas as being typical of this entity. Both sides were examined in three of the cases. Neither tumour vessels arising from the extradural part of the carotid siphon nor other tumour vessels were evident in any of the cases.

SUMMARY

Carotid angiography was performed in 31 cases of chromophobe adenoma. Dilated vessels arising from the extradural part of the carotid siphon and feeding the capsule of an intrasellar and suprasellar tumour strongly suggest it being a chromophobe adenoma.

ZUSAMMENFASSUNG

Angiographie der Arteria carotis wurde in 31 Fällen von chromophobem Adenom vorgenommen. Erweiterte Äste des extraduralen Abschnittes des Siphons der Arteria carotis, die zur Kapsel eines intra- und suprasellären Tumors laufen, sprechen für ein chromophobes Adenom.

RÉSUMÉ

Les auteurs ont fait des angiographies carotidiennes dans 31 cas d'adénome chromophobe. La présence de vaisseaux dilatés provenant de la partie extra-durale du siphon carotidien et irriguant la capsule d'une tumeur intra- et suprasellaire est un fort argument en faveur d'un adénome chromophobe.

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MITRAL DOME FORMATION IN AORTIC VALVULAR DISEASES

by

KJELL BERGSTROM and HERMAN LODIN

BJORK & LODIN (1960) have stated that there would appear to be no indication for left ventricular angiocardiography in the evaluation of the mitral stenotic component of valvular lesions However these authors observed a clearly outlined contrast free area at the site of the mitral orifice in diastole in certain of the left ventricular angiocardiograms This roentgenologic appearance was correlated to clinical observations and findings at operation The results may be summarized as follows No mitral dome was observed in cases where clinical signs of mitral stenosis were absent and mitral stenosis was found at operation in all the twenty operated cases in which a dome had previously been observed in all but one of these cases the mitral stenosis was advanced The contrast free area was due to fused mitral cusps which caused a domelike protrusion into the ventricular contrast accumulation Certain criteria were used in defining dome formation The dome should be observable in both the frontal and lateral planes and its whole circumference should be clearly outlined in the frontal plane BJORK & LODIN made the reservation however that if the ventricle were greatly enlarged mitral stenosis might be present

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Furthermore, the vessels in the chromophobe adenomas were not as extensive as in meningiomas located in the same area (Fig 6)

The carotid angiograms of 10 cases of craniopharyngeomas were also examined in an attempt to evaluate the appearances of tumour vessels in chromophobe adenomas as being typical of this entity Both sides were examined in three of the cases Neither tumour vessels arising from the extradural part of the carotid siphon nor other tumour vessels were evident in any of the cases

SUMMARY

Carotid angiography was performed in 31 cases of chromophobe adenoma Dilated vessels arising from the extradural part of the carotid siphon and feeding the capsule of an intrasellar and suprasellar tumour strongly suggest it being a chromophobe adenoma

ZUSAMMENFASSUNG

Angiographie der Arteria carotis wurde in 31 Fällen von chromophobem Adenom vorgenommen Erweiterte Äste des extraduralen Abschnittes des Siphons der Arteria carotis *die zur Kapsel eines intra und suprasellären Tumors laufen sprechen für ein* chromophobes Adenom

RÉSUMÉ

Les auteurs ont fait des angiographies carotidiennes dans 31 cas d adénome chromophobe *La présence de vaisseaux dilatés provenant de la partie extra durale du siphon carotidien* et irriguant la capsule d une tumeur intra et suprasellaire est un fort argument en faveur d un adénome chromophobe

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Table 1

Distribution of case material according to diagnosis method of examination and appearance of mitral dome formation (the latter being indicated by the numbers given within brackets)

Diagnosis	Number of cases	Ventricular puncture	Retrograde catheterization	Transseptal catheterization	Total with dome formation
Aortic stenosis	26	13 (3)	4 (1)	9 (5)	9
Aortic insufficiency	30	12 (2)	17 (1)	1	3
Aortic stenosis and insufficiency	19	10 (3)	6 (1)	3 (2)	6
Total	75	35 (8)	27 (3)	13 (7)	18

followed by one to two films per sec Alternating exposures with a maximum exposure frequency of three films per sec were employed in one case ECG, injection time exposures and peripheral arterial pressure were recorded during the contrast medium injection The injection was preceded by recording of the left ventricular and atrial pressure and the pulmonary capillary venous pressure (PCV) (see CULLHED 1964) The total cardiac volume was calculated according to JONSELL (1939) and the left ventricular volume according to ARVIDSSON (1961)

Results and Discussion

The angiocardiographic findings and the pressure values obtained at the catheterizations are presented in Table 2 A typical mitral dome was observed in 13 of the cases in both frontal and lateral projections In four of the cases this observation was only made in the lateral projection but the left ventricle in these cases was greatly enlarged In one case dome formation was observed in the frontal plane but as alternating exposures were used the frontal and lateral films were not directly comparable Adequate left ventricular contractions on mitral dome evaluation were evident in all cases

The dome in mitral stenosis is formed by the fused cusps which protrude like a pouch into the left ventricle Because the valves are unable to open completely an accumulation of contrast free blood forms between them in the ventricle This area becomes clearly delineated partly because the valves are thickened and partly because they are less mobile and thus demonstrated tangentially The false mitral dome in the present series appears to require



Left ventricular angiograms after direct puncture in Case 2 diastole typical mitral dome formation in both planes No elevation of LV_{ED} or any significant gradient over the mitral valves

even if the dome was evident in the lateral projection only In addition it was emphasized that the extensive bulging sometimes made by the left atrium into the ventricular contrast medium should not be confused with a mitral dome Such atrial bulging is, however, constant in both systole and diastole

Since publication of the above study, dome formation of the mitral valves has been observed in a number of cases of aortic valvular disease, without there being any evidence of mitral stenosis on catheterization or operation A more detailed analysis of these cases with false mitral dome formation therefore seemed justified, a series of cases of pure aortic valvular disease have thus been investigated

Material The series comprises 75 cases of aortic valvular disease, in 18 of which false mitral dome formation was present The distribution of the series, with regard to diagnosis investigation technique, and the presence of a false mitral dome, is given in Table 1

Method Eight of the 18 mitral dome cases were observed after left ventricular puncture, three after retrograde catheterization of the aorta and left ventricle, and seven after transseptal catheterization with injection into the left ventricle In all cases, 1 to 1 5 ml per kg bodyweight of Urografin 76 % was used The maximum exposure time was 0 03 sec and the exposure frequency was six simultaneous films per sec during the injection period, then

caution In two of the seven instances (Cases 6 and 17) in which transeptal catheterization was performed and the injection given through the catheter introduced into the left ventricle, the catheter position may have contributed to a reduction in the mitral cusp mobility The catheter in these two cases had looped around the orifice and might thus have interfered with the chordae tendineae In the remaining five cases of transseptal catheterization on the other hand the catheter lay in the centre of the mitral orifice at the start of the injection with its tip directed downwards towards the apex Typical dome formation in one of these cases was noted even after the catheter had passed into the left atrium

An explanation must therefore be sought elsewhere in sixteen of the cases of dome formation An increased end diastolic pressure indicates impediment to left atrial evacuation With the gradient between the left atrium and ventricle practically eliminated the mobility of the mitral cusps would be reduced and retarded and combined with special anatomical conditions, this could in certain cases give rise to dome formation Examination of the material from this viewpoint gave the following results

Taking 10 mm Hg as an upper normal limit for the end diastolic pressure of the left ventricle, this value was found to be exceeded in 48 out of the total of 75 cases examined and in 11 of the 16 cases with dome formation Of the remaining five cases of dome formation (Cases 2 9, 12 15 18), which on preoperative catheterization had no increase in end diastolic pressure three cases (Cases 12 15 and 18) were found to have end diastolic values of 10, 14 and 15, respectively at operation Reservation must be made however for possible errors in these pressure measurements (CULLHED) Two cases remain (Cases 2 and 9) in which the end diastolic pressure was normal on repeat catheterization with maximal values of 4 mm and 7 mm Hg respectively Unequivocal dome formation was seen in both planes in the former of those cases as shown in the roentgenograms From the view in systole it could however, be seen that the anterior cusp extended unusually far medially and probably was attached to the septum A valve anomaly may thus have been present No explanation for the other case can be offered

These false dome formations appear regardless of the total cardiac volume or the left ventricular systolic or diastolic volume as may be seen from Table 2 and the left ventricular systolic pressure seems to play no role It is possible however that certain other factors may contribute to false dome formation even though there is no evidence in the present material of such influence It is conceivable that blood regurgitating from the aorta in severe *aortic insufficiency* may exert a limiting effect on the movements of the *anterior* mitral cusp It is also possible that in aortic stenosis with considerable hyper

Table 2

Analysis of cases with mitral dome formation — Numbers within brackets indicate values obtained at operation

	Diagnosis		Technique	Dome F	Dome L	Total volume ml	LV volume Syst ml	LV volume Diast ml	Pressure mm Hg LV	Pressure mm Hg LV_{ED}	Pressure mm Hg PCV mean
1	AS		VP	F	F	760	70	240	160	12	10
2	AS		VP	F	F	440	30	160	150	4	9
3	AS		VP	F	L	950	40	170	210	15	6
4	AS		R	F		950	90	230	160	19	16
5	AS		TS	F	F	230	5	170	210	14	15
6	AS		TS	F	F	420	20	250	130	9	5
7	AS		TS	F	F	580	20	210	210	10	9
8	AS		TS	F	F	890	30	180	215	20	7
9	AS		TS	F	F	1 100	20	150	260	7	6
10	AI		VP		F	1 070	180	480	140	12	6
11	AI		VP		F	1 000	170	600	160	12	4
12	AI		R	F	F	1 170	190	530	140	8 (10)	14
13	AS	AI	VP		F	1 360	170	360	190	36	38
14	AS	AI	VP		F	1 100	130	360	220	18	None obtained
15	AS	AI	VP	F	F	1 500	70	400	200	7 (14)	12
16	AS	AI	R	F	L	1 430	200	450	260	21	20
17	AS	AI	TS	F	F	1 180	120	360	180	15	8
18	AS	AI	TS	F	F	810	80	420	165	5 (15)	8

F — *frontal projection* L — *lateral projection* LV — *left ventricle* LV_S — *systolic pressure in left ventricle* LV_{ED} — end diastolic pressure in left ventricle PCV — pulmonary capillary venous pressure

a similar mechanism for its formation Normal valves which are thin and move rapidly cannot be observed with the technique used Reduced mobility of the mitral valves without organic changes may provide the necessary conditions for an effective tangential ray direction and thus enable the demonstration of a defect in the ventricular contrast accumulation provided the blood between the mitral cusps does not contain any contrast medium

Possible technical causes for a reduction in valve mobility may lie in the position of the needle on ventricular puncture and of the catheters on retrograde and transseptal catheterization In none of the cases of ventricular puncture or retrograde catheterization was the needle or catheter position such that any hindrance to mitral valve movement could be expected As regards the transseptal catheterizations, it should first be pointed out that valves that are passed by a catheter must be evaluated with the greatest

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INTRASPLENIC ARTERIAL ANEURYSMS FOLLOWING SPLENOPORTAL PHLEBOGRAPHY

by

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Aneurysms of the splenic artery are considered rare but are observed more often in patients with an enlarged spleen and portal hypertension than in others (OWENS & COFFEY 1953) All previously described splenic arterial aneurysms have been located in the extrasplenic part of the artery

Selective celiac and superior mesenteric angiography have often been performed in our department following splenoportal phlebography in patients with portal hypertension In some of these patients intrasplenic arterial aneurysms have sometimes been found at angiography in an area corresponding to the position of the needle or the contrast medium deposit in the earlier splenoportal phlebography These observations have prompted a review of the angiographic material in which splenoportal phlebography preceded celiac angiography

Material Fifty five patients had had splenoportal phlebography before celiac or splenic angiography Most of them had cirrhosis with or without portal hypertension but also other indications for both studies had been present (e g bleeding from the gastrointestinal tract enlarged spleen trauma to the liver)

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trophy of the ventricular wall without simultaneous dilatation, the hypertrophic outflow region may reduce the mobility of the anterior mitral cusp. Finally, *slightly to moderately* thickened mitral cusps (due to endocarditic changes), with open commissures though, may contribute to dome formation.

Conclusion

It is evident from this material that a so called 'typical mitral dome' in cases of aortic valvular disease must be judged with great caution. This must be so especially in cases of raised end diastolic pressure in the left ventricle and when the transseptal catheterization technique is used. Increased end diastolic pressure without a simultaneous pressure gradient between atrium and ventricle is strong evidence against the mitral dome being due to stenosis. Evidence in support of the view that a dome may be false is also obtained if the transseptally introduced catheter lies in the immediate vicinity of the annulus, which indicates that at least one commissure is completely open.

SUMMARY

A false mitral dome was observed in 18 of a series of 75 cases of aortic valvular disease. These eighteen cases are analysed. In fourteen the end diastolic pressure in the left ventricle was found to be raised. Explanations for the dome formation are presented.

ZUSAMMENFASSUNG

In einer Folge von 75 Fällen von Aortenklappenfehlern konnte 18mal ein falscher Mitraldom beobachtet werden. Diese Fälle wurden systematisch untersucht und in vierzehn wurde der enddiastolische Druck im linken Ventrikel erhöht gefunden. Es wird versucht die Entstehung des Mitraldomes zu erklären.

RÉSUMÉ

Les auteurs ont observé un faux dome mitral dans 18 cas sur une série de 75 cas d'affection valvulaire aortique. Ils analysent ces 18 cas et ont trouvé une élévation de la pression télédiastolique dans le ventricule gauche dans 14 cas. Ils proposent des explications de la formation de ce dome.

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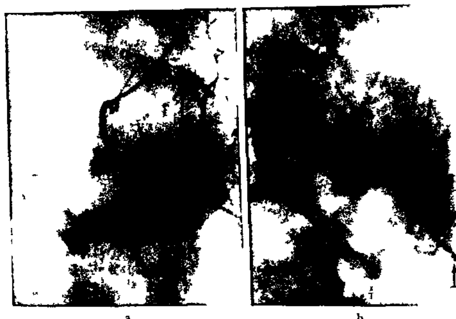


Fig 2 Cirrhosis of the liver and portal hypertension in a woman aged 39 Twenty months previously contrast medium had been injected into a branch of the splenic artery and into the splenic vein at splenoportal phlebography (a) A portocaval shunt was performed and 8 months later a repeat injection was made into the lower pole of the spleen At celiac angiography (b) two intrasplenic aneurysms were found One 6 mm by 6 mm in size (—→) corresponded to the site of the earlier arterial puncture and the second 4 mm by 4 mm in size (↦) to the second splenic puncture

ed to the site of injection of contrast medium or to the position of the needle The various changes with multiple aneurysms could be referred either to repeated splenic punctures (Fig 1) or to one single injection

The spleen changed in size and position from one examination to the next an absolute correlation between the position of the aneurysms evident at angiography and the needle position during splenoportal phlebography could therefore not be made However the relative position of the aneurysm in 7 patients was in accordance with the site of the splenic injection Verification was possible in one patient because the contrast medium was partly injected into an intrasplenic arterial branch (Fig 2) An arterial aneurysm 6 mm in diameter was present at the puncture site

The contrast injection in one patient with one intrasplenic arterial aneurysm could not be correlated with the location of the aneurysm The patient had had three splenoportal phlebograms before angiography but only two were available for review The contrast medium had in these studies been deposited in the



Fig. 1. Cirrhosis of the liver and portal hypertension in a woman aged 23 years who 5 years previously had had splenoportal phlebography performed prior to (a) and after (b) a portocaval shunt. At selective splenic angiography (c) two intrasplenic arterial aneurysms were found, one 9 mm by 3 mm in size being located in the intermediate part (⟶) and the other 6 mm by 6 mm in the lower pole (↦) of the spleen. The spleen had decreased in size from 16 cm to 12 cm. The relative locations of the two aneurysms corresponded to the sites of the injection.

The main indication for angiography was to demonstrate any abnormality within the liver and the portal system. Thirteen patients were therefore excluded because the splenic arterial system was not completely demonstrated. Of the remaining 42 patients, 32 had portal hypertension, but eight of these had a patent end to side portacaval shunt, and 10 had neither clinical nor roentgenologic signs of portal hypertension.

The interval between splenoportal phlebography and celiac angiography varied as widely as from six years to one day. Fifteen patients had been examined with more than one splenoportal phlebography before celiac angiography, two patients had had four, four had had three, and nine patients had had two examinations.

A control group, in which no splenic puncture had been made before angiography, included fifteen patients with portal hypertension and twenty five patients with normal pressures.

Results

Nine of the 42 patients who had had splenoportal phlebography prior to angiography had intrasplenic arterial aneurysms at the latter examination. Five of the patients had one and four had two aneurysms. No intrasplenic aneurysms were observed in the control group.

Intrasplenic aneurysms were thus observed only in those patients who had had previous splenic puncture and who also had portal hypertension. The position of the aneurysms in the spleen in 8 patients (12 aneurysms) correspond



Fig 4 Portal hypertension and cirrho is of the l ver in a woman aged 56 The punctu e site at splenop rtal phlebog aphy (a) corre ponded to a 6 mm by 5 mm ntr splen c aneurysm (→) pre ent t ang ography perfo med 1 year and 10 months after the punctu e (b and c) The splen c rtery wa tortuous and thre extrasplen c aneurysms (↦) w re e dent at the h lum The two l rg an u ysms measuring 25 mm and 10 mm had mural calc fications

mm) were observed in those patients who were studied by angiography less than a year after splenoportal phlebography (Fig 2) In six patients the interval was one year or more between the two studies and each had an aneurysm varying in size between 6 mm and 9 mm (mean = 7 5 mm (Figs 1, 2 and 4

Varying degrees of vascular changes were observed in the intrasplenic arterial branches in all the patients with portal hypertension and this made an evaluation of small intrasplenic aneurysm difficult Anteroposterior and oblique projections were used in most of the examinations and the aneurysms reported could therefore be distinguished from arterial tortuosity and irregularity The hilum of the spleen usually cannot be exactly defined It was therefore sometimes difficult to determine whether an aneurysm was located within the parenchyma or in the hilum (Figs 4 and 5) Examination in different projections facilitated the localization of the lesions

Discussion

Aneurysms of arterial branches in the splenic parenchyma have not been observed previously although they have been seen in branches close to the



Fig 3 Cirrhosis of the liver and portal hypertension in a man aged 32 years he had had a portocaval anastomosis when he was 26 Splenoportal phlebography was performed 6 and 5 years previously on three occasions Selective splenic arteriography revealed an 8 mm intrasplenic aneurysm at the upper pole (⟶) *of the spleen not corresponding to two of the splenic injec*tions the third was not available for review Marked intra splenic arterial changes evident

lower pole, while the aneurysm lay in the upper pole It is assumed that the first splenic puncture, which had been performed 6 years previously, had produced the aneurysm

There was definite correlation between the splenoportal phlebography/celiac angiography time interval and the appearance of the aneurysm In 17 of 32 patients with portal hypertension, who had had celiac angiography less than six weeks after a single splenic puncture no intrasplenic aneurysms were observed In the remaining 15 patients, in whom the time interval between splenoportal phlebography and angiography was between 6 weeks and 6 years, nine had one or more aneurysms (13 aneurysms in all were present in these patients)

In 10 patients, who had a normal portal pressure and in whom splenoportal phlebography *had been performed before angiography no intrasplenic* arterial aneurysms were observed, in four of these the time interval was more than 6 weeks

The size of the intrasplenic aneurysms varied between 3 mm and 9 mm as measured on the films The smallest aneurysms (3 mm to 5 mm, mean = 4 3



Fig 6 Cirrho of the li er and portal hypertension s nce the age of 14 a woman ag d 25 Fou years pre ously she h d had a portocaval shunt op ration The ana tomos was however not patent and a splenorenal nastomosis wa perfo med At plenopo tal phl bography two and th ee y ars p or to splenectomy the needle had been posit oned in the lower pol of th pleen at site whe e later nt asplen c aneurysms (→) were observ d at a gi g phy of the oper tion spec men (a and b) Aneury ms (↦) w e also obse ed in the lowe and upper pa t of the splenic h lum The aneury ms w e later verified h stolog cally

portal hypertension had undergone splenectomy and arteriography of the upper and lower polar arteries The operation specimen revealed two intra splenic aneurysms of the lower pole corresponding to two previously performed splenic punctures (Fig 6) Hilar aneurysms were also observed two in the lower part and one in the upper part of the spleen Histologic examination of the lower lobe of the spleen confirmed the presence of true aneurysms these had the same appearances as the hilar aneurysms with local destruction of the intima and media This case as well as the remainder of cases brought conclusive evidence of a direct relationship between the position of the needle at splenoportal phlebography and local changes within the intrasplenic arterial tree



a b

Fig. [illegible]. Cirrhosis of the liver and portal hypertension in a woman aged 60. Splenoportal phlebography had been performed twice 3 years previously, on both occasions the puncture was made into the lower pole of the spleen. At selective splenic angiography (a and b) two aneurysms were observed. One, 7 mm by 7 mm in size, was located in the lower pole (⟶) of the spleen, while a second aneurysm 12 mm by 1[illegible] mm in size lay at the splenic hilum (⟷). Only the former was related to the splenic injections. The direction of the catheter was not towards the second aneurysm.

hilum (WARD McQUAID 1958). Aneurysms located in the peripheral branches cannot be demonstrated unless selective celiac angiography is performed. Lumbar aortography has been used in several instances to demonstrate calcified aneurysms of the splenic artery (WAGNER 1946, WAGNER et coll. 1947, SMITH et coll. 1952, BERGER et coll. 1953, FELSON 1954, DOWNS et coll. 1955, RIEMENSCHNEIDER 1955, STEINBERG 1960, STEINBERG & LORD 1960, SPITTEL et coll. 1961, STEINBERG et coll. 1961). ROSCH & BRET (1962), using selective celiac angiography, also demonstrated aneurysms of the main stem of the splenic artery. SPITTEL et coll. maintained, on the other hand, that selective angiography should not be performed in the study of aneurysms in the splenic artery, their reason being that aneurysms in other abdominal vessels might be missed. We feel that it is of advantage to inject the contrast medium selectively, even if it is necessary to catheterize all the main branches of the lumbar aorta, because then it becomes possible to demonstrate such small intrasplenic aneurysms as were observed in our material. It is still better to inject the contrast medium selectively into the splenic artery because superimposition of contrast filled vessels which may confuse the interpretation will then be prevented.

After the preparation of the present material was completed, a patient with



a b

Fig 6 Cirrhosis of the liver and portal hypertension since the age of 14 in a woman aged 25 Four years previously she had had a portocaval shunt operation The anastomosis was however not patent and a splenorenal anastomosis was performed At splenoportal phlebography two and three years prior to splenectomy the needle had been positioned in the lower pole of the spleen at sites where later intrasplenic aneurysm (⟶) were observed at angiography of the operation specimen (a and b) Aneurysms (↦) were also observed in the lower and upper part of the splenic hilum The aneurysms were later verified histologically

portal hypertension had undergone splenectomy and arteriography of the upper and lower polar arteries The operation specimen revealed two intrasplenic aneurysms of the lower pole corresponding to two previously performed splenic punctures (Fig 6) Hilar aneurysms were also observed two in the lower part and one in the upper part of the spleen Histologic examination of the lower lobe of the spleen confirmed the presence of true aneurysms these had the same appearances as the hilar aneurysms with local destruction of the intima and media This case as well as the remainder of cases brought conclusive evidence of a direct relationship between the position of the needle at splenoportal phlebography and local changes within the intrasplenic arterial tree



Fig. 5. Cirrhosis of the liver and portal hypertension in a woman aged 60. Splenoportal phlebography had been performed twice 3 years previously, on both occasions the puncture was made into the lower pole of the spleen. At selective splenic angiography (a and b) two aneurysms were observed. One 7 mm by 7 mm in size was located in the lower pole (⟶) of the spleen while a second aneurysm 12 mm by 15 mm in size lay at the splenic hilum (⟷). Only the former was related to the splenic injections. The direction of the catheter was not towards the second aneurysm.

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in this material. This may be explained by the fact that splenoportal phlebography does not remove any tissue and that the instrument used is smaller than the one employed at biopsy. The anatomic distribution of arteries and veins in the spleen may be another factor of importance. Injection of the contrast medium near the splenic hilum in order to achieve the best possible visibility of the veins has been recommended (ESSER 1964, MAURER et coll. 1964). This study suggests that it is better to avoid the splenic hilum and inject the contrast medium as far out in the periphery of the spleen as possible.

Splenoportal phlebography carries more potential risk than has been claimed. Spontaneous rupture of the spleen has been observed in a few patients with portal hypertension although the reason for this has not been fully explained (WOHL 1925, ABRAMS & KAUDER 1944, inter alios). Intrasplenic arterial aneurysms and arteriovenous fistulas may perhaps cause spontaneous rupture but so far this complication has not been documented. The present investigation concerned the roentgenologic evaluation of splenic arterial aneurysms and the clinical course of the patients has therefore not been followed. Because of the potential dangers present, future intentions include a clinical as well as a roentgenologic follow up of that part of the material in which aneurysmal changes were demonstrated.

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SUMMARY

Intrasplenic arterial aneurysms were observed in a group of 42 patients who had been examined by splenoportal phlebography prior to selective celiac angiography. All aneurysms were observed in patients who had portal hypertension or who had been operated upon for that condition.

ZUSAMMENFASSUNG

Milzaneurysmen wurden in einer Serie von 4[illegible] Patienten angetroffen, die mittels splenoportaler Phlebographie untersucht wurden, bevor man die selektive Arteriographie der Art. coeliaca ausführte. Alle Fälle von Milzaneurysma hatten portalen Hochdruck oder waren früher wegen diesem operiert worden.

RÉSUMÉ

Les a[illegible]rs ont observé des anévrismes artériels intraspléniques parmi un groupe de 42 malades qui avaient subi une phlébographie splénoportale avant l'angiographie sélective du tr[illegible] cœliaque. [illegible]

The following observations have been made in the present study

1 Local intrasplenic arterial aneurysms were observed in a third of the patients with portal hypertension who had previously been examined by splenoportal phlebography, no such changes were observed in the control group This indicates a direct relationship between the splenic puncture and the local arterial changes The arterial changes caused by the portal hypertension seem to be the main cause of aneurysms following puncture

2 Correlation was obtained between the site of the needle at splenoportal phlebography, and the site of the aneurysm was established in 12 of the 13 intrasplenic aneurysms present

3 The contrast medium in one patient was directly injected into a branch of the splenic artery during splenoportal phlebography The site of the aneurysm was found exactly to correspond to the site where the puncture had been made Accidental intra arterial injections in splenoportal phlebography have previously been observed by ARNER & FERNSTROM (1960), and arterial perforations may easily occur during blind puncture of the spleen

4 The time interval between the splenic puncture and angiography indicates a positive correlation between splenoportal phlebography and the local arterial changes Despite the fact that 23 patients had had one splenic puncture performed less than 6 weeks before angiography, there was no intrasplenic arterial aneurysm in this group All the intrasplenic aneurysms (9 patients, 13 aneurysms) were observed in the group of 15 patients with portal hypertension studied after a period of six weeks to six years between the puncture and the angiographic examination, suggesting that the splenic puncture and the contrast medium injection were the cause of the local arterial disease Before 6 weeks, the aneurysms are probably too small to be demonstrated at angiography

5 The aneurysms became larger with increasing time interval between puncture and angiography, this also suggests that splenoportal phlebography was the cause of the aneurysms

Arterial puncture and catheterization of the femoral artery may sometimes give rise to arterial aneurysms and arteriovenous fistulas (BERGENTZ et coll 1966) This is however a rare complication and can usually be prevented if effective compression is applied at the puncture site If a splenic artery is punctured during splenoportal phlebography, compression cannot be applied after withdrawal of the catheter Aneurysms may therefore occur when the arteries have undergone degenerative changes due to portal hypertension

It is well known that biopsy of the kidney and the liver may cause arteriovenous fistulae (BOIJSEN & KOHLER 1962, FERNSTROM & LINDBLOM 1962, DEBRAY et coll 1965) There were no signs of arteriovenous communications

in this material. This may be explained by the fact that splenoportal phlebography does not remove any tissue and that the instrument used is smaller than the one employed at biopsy. The anatomic distribution of arteries and veins in the spleen may be another factor of importance. Injection of the contrast medium near the splenic hilum in order to achieve the best possible visibility of the veins has been recommended (ESSER 1964, MAURER et coll. 1964). This study suggests that it is better to avoid the splenic hilum and inject the contrast medium as far out in the periphery of the spleen as possible.

Splenoportal phlebography carries more potential risk than has been claimed. Spontaneous rupture of the spleen has been observed in a few patients with portal hypertension although the reason for this has not been fully explained (WOHL 1925, ABRAMS & KAUDER 1944, inter alios). Intrasplenic arterial aneurysms and arteriovenous fistulas may perhaps cause spontaneous rupture but so far this complication has not been documented. The present investigation concerned the roentgenologic evaluation of splenic arterial aneurysms and the clinical course of the patients has therefore not been followed. Because of the potential dangers present, future intentions include a clinical as well as a roentgenologic follow-up of that part of the material in which aneurysmal changes were demonstrated.

Acknowledgement

This work was supported by a grant from Statens Medicinska Forskningsråd.

SUMMARY

Intrasplenic arterial aneurysms were observed in a group of 42 patients who had been examined by splenoportal phlebography prior to selective celiac angiography. All aneurysms were observed in patients who had portal hypertension or who had been operated upon for that condition.

ZUSAMMENFASSUNG

Milzaneurysmen wurden in einer Serie von 42 Patienten angetroffen, die mittels splenoportaler Phlebographie untersucht wurden, bevor man die selektive Arteriographie der Arteria coeliaca ausführte. Alle Fälle von Milzaneurysma hatten portalen Hochdruck oder waren vorher wegen diesem operiert worden.

RÉSUMÉ

Les auteurs ont observé des anévrismes artériels intraspléniques parmi un groupe de 42 malades qui avaient subi une phlébographie splénoportale avant l'angiographie sélective du tronc coeliaque. Tous ces anévrismes ont été trouvés chez des malades atteints d'hypertension portale ou opérés pour cette affection.

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THYROID ANGIOGRAPHY

by

I Wickbom B F Zachrisson and P Heimann

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For the interpretation we had to begin with to rely on our experience in other fields of angiography We found little of help in the literature since only a few papers have dealt with the subject (Bobbio et coll 1959 and de Nunno et coll 1963) We therefore reviewed our own cases up to date to gather the information we could obtain from these Before reporting upon the results of

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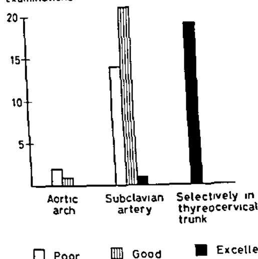


Fig 1 Contrast filling of the thyroid lobe after injection into different vessels

try to place the tip of the catheter just at the origin of the thyrocervical trunk the position is checked by first injecting a small amount of contrast medium under fluoroscopic control Thereafter we inject 15 to 20 ml Urografin 60 % by hand the injection time usually being 2 to 3 seconds Stereoscopic films are obtained with two tubes forming an angle of 8 We use the Elema Schonander film changer (AOT) and in each series usually produce the first six films at 0 5 sec intervals followed by 3 to 4 films at 2 sec intervals

The stereoscopic technique has proved most useful particularly in the analysis of small vessels and has in addition reduced the inconvenience of superimposition of calcifications and bony structures The subtraction method has also proved helpful for the same purpose If superimposed structures still interfered with the interpretation an additional series in the oblique position was produced

However the contrast filling often varies in the different series of films of the same case and the density of the smaller vessels is generally too poor to permit reliable interpretations In recent years therefore subclavian angiography has usually been followed by an attempt to inject contrast medium selectively into the thyrocervical trunk A small bend given to the catheter near to its tip facilitates the introduction into the trunk the degree of bending being adapted to the appearance of the vessel in the previous subclavian angiogram Catheterization of the trunk is not always easy in particular not

the review, however, a brief description of the normal anatomy and of the technique used will be given.

Anatomy. The thyroid gland is mainly supplied by two pairs of arteries, the inferior or caudal thyroid artery, and the superior or cranial thyroid artery. In some ten per cent of cases a fifth artery, the thyroidea ima, usually arising from the brachiocephalic trunk, supplies a small part of the gland. The thyrocervical trunk arises from the subclavian artery, generally about 1 cm distal to the vertebral artery, and after a short upward course divides into four arteries: the suprascapular, the superficial cervical, the ascending cervical and the inferior thyroid artery. The transverse colli artery also sometimes arises from the thyrocervical trunk. The inferior thyroid artery usually runs a fairly typical S shaped course, first medially and then in a loop with its convexity directed upwards, followed by another loop curling downwards. Within the gland, it gives off a small number of branches of moderate size, which run a slightly curved course. It is usually not possible to distinguish smaller branches, but 2 to 3 seconds after the injection the whole gland becomes uniformly 'stained', indicating a rich network of capillaries and other vessels too small to be identified individually. The ascending cervical artery takes off from the thyroid artery where it bends medially and runs upwards in the groove between the m. scalenus anterior and the m. longus capitis near the phrenic nerve. The cervical superficial artery is also fairly close to the thyroid; this artery is sometimes a superficial branch of the transverse colli artery. The superior or cranial thyroid artery generally arises from the external carotid artery just distal to the bifurcation, or in some cases from the internal or the common carotid artery near its bifurcation. It usually supplies the upper pole and part of the isthmus. An anastomosing trunk courses over the back of each lobe and unites the inferior and superior thyroid arteries.

Technique. BOBBIO et coll. injected 20 ml Renografin 70 % during about 3 sec, following direct puncture of the subclavian artery. We feel that with this technique it must be difficult to avoid the risk of injecting most of the highly concentrated contrast medium into the vertebral artery and so produce serious cerebral complications. DE NUNNO et coll. inserted a catheter through the brachial artery after open exposure and tried to place the tip of the catheter in the subclavian artery at the origin of the thyrocervical trunk.

We prefer to insert the catheter (Green Kifa with side holes) percutaneously from the axillary artery. At first the brachial artery was often punctured, but transient ischemia of the arm occurred in two cases, after the procedure, wherefore a change was made to the axillary approach; since then no complications have arisen apart from a few local hematomas of moderate size. We

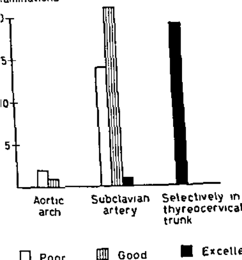


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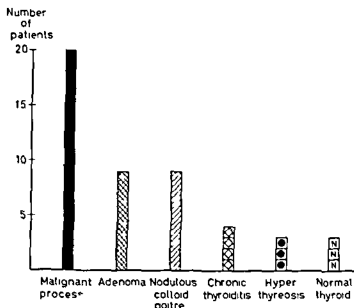


Fig 2 Pathologic diagnoses as obtained from the microscopic examination in 48 cases of the material reviewed

in cases where it arises at an acute angle Failure occurred in 9 out of 27 attempts

As may be seen from Fig 1, the contrast filling and accordingly the diagnostic value is so much superior with this selective technique that it ought always to be attempted if a definite diagnosis cannot be made on the basis of the subclavian angiogram Only 3 to 10 ml Urografin 60 % is needed for the selective examination, depending on the size of the trunk as established by the subclavian injection

For a complete investigation, the superior thyroid artery should of course also be examined In 14 out of 34 right side cases a faint filling of this vessel was seen when the contrast medium was deposited in the subclavian artery or in the brachiocephalic trunk, but the accumulation of the medium was usually too poor to be of diagnostic value

In 7 cases, in which we had reason to suspect that this vessel carried the major blood supply (Fig 9), the common carotid artery was also injected after direct puncture In one of these cases a fairly large hematoma developed which made the dissection at the subsequent operation difficult We have since then confined the examination to the inferior thyroid artery, and this has so far proved sufficient in most cases In exceptional cases when the superior thyroid artery constitutes the main supply it may be necessary to inject the carotid artery (cf Fig 9) To avoid the risk of causing a hematoma in the neck the injection can be made through a catheter introduced from the axillary or femoral artery

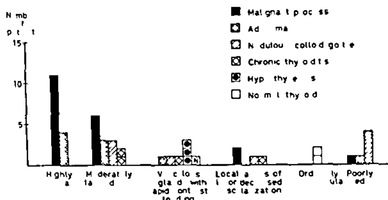


Fig 3 Degree of vascularity observed in the angiograms of 48 cases

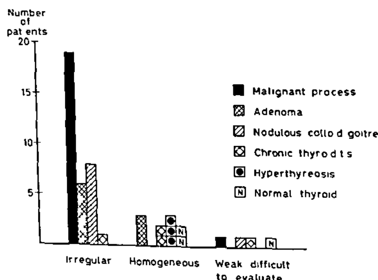


Fig 4 Contrast loading as appreciated from angiograms in 48 cases

Material The present material consists of 56 cases in 50 of which the gland had later been partially or completely removed In three cases needle biopsy alone was performed and in one case only autopsy Included in the material are also one case of inoperable growth in which not even biopsy had been performed as well as one case of metastases from a hypernephroma

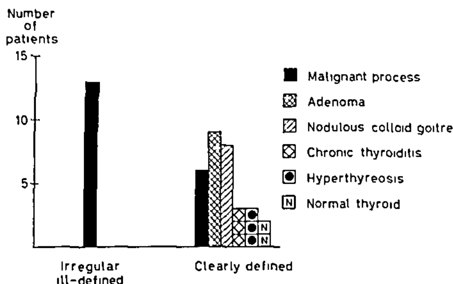


Fig 5 Appreciation of the definition of the contrast loaded lobe in 44 cases of the material reviewed

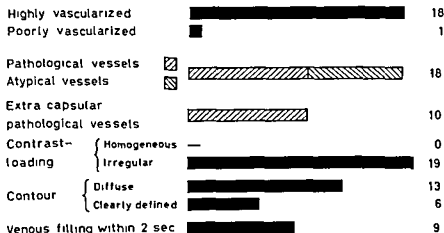


Fig 6 Appreciation of the vascularization and contrast loading in 20 cases of malignant lesions in the material reviewed

in which the diagnosis was considered definite when the clinical signs were considered in combination with the angiographic findings

The angiograms from these 56 cases have been reviewed by the two radiologists of the group (W and Z), the classification in the diagrams of Figs 3 to 6 was made by W who then had no knowledge of the final diagnosis Eight cases were excluded because the thyroid vessels were too poorly outlined to enable interpretation (All of these were from the first period of study, when



g / C e 1 (norm l) Selec e ng ography of the right yrocerv cal trunk inferior yro d artery (⟶) and verte l a tery (↔)



Fig 8 Case 2 Hyperthyreosis Subclavian arteriogram (left) Both the superior (↦) and inferior (⟶) thyroid arteries are wide the whole lobe is homogeneously contrast loaded already in this phase and is sharply outlined Selective injection (right) into the thyrocervical trunk in a somewhat later phase than for the subclavian arter ogram The stain ng is more dense dilated veins have started to fill the contour of the upper pole is not quite sharp probably because the blood supply from the superior thyroid artery was not opaque

the contrast medium was injected only into the subclavian artery or into the brachiocephalic trunk) The results of microscopy in the remaining 48 cases have been tabulated in Fig 2 Almost 50 per cent were malignant growths which is natural since the examination was usually performed because of clini cally suspected malignancy

Results

When reviewing the angiograms we had primarily the following considera tions in mind (1) vascularity (Fig 3) contrast staining (Fig 4) (3) the definition or the contours of the thyroid lobe in the capillary phase (Fig 5) (4) the presence of abnormal vessels (Fig 6) and (5) vascular supply from arteries other than the thyroid arteries (ascending or superficial cervical arteries)

The expression highly or moderately vascularized in Fig 3 means that more vessels could be seen than is normal The small group classified as vasculous glands with rapid contrast loading contained no great number of vessels individually distinguishable but the contrast loading was more

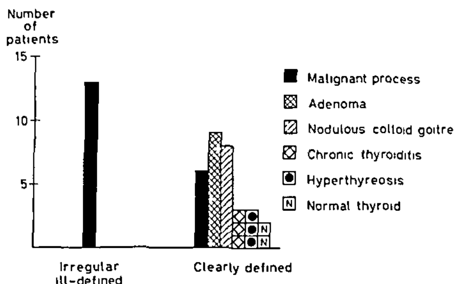


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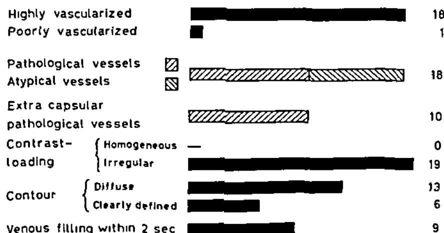


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Fig 7 Case 1 (normal) Selective angiography of the right thyrocervical trunk Inferior thyroid artery (⟶) and vertebral artery (⟶)



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Fig 9 Case 3 Recurrent hyperthyreosis Subclavian injection *(left) and common carotid artery injection (right) The superior* thyroid artery (↔) is wider than the inferior and supplies the major portion of the lobe which already in this phase is opaque



Fig 10 Case 4 Follicular aden*oma late arterial phase The* contrast staining is well defined but is not as homogeneous as in figs 8 and 9

marked and it appeared earlier than is normal, the main arteries were also wider than in normal cases

The contrast loading was irregular in all but one of the malignant cases (Fig 4), the exception being a poorly vascularized gland The loading in several adenomas was however more or less irregular (Fig 10 and 11) The irregularity probably corresponded to a varying degree of activity within the gland, those parts containing a large amount of colloid being poorly vascularized whereas the more active parts were rich in vessels Avascular areas may of course also be due to necrosis or hemorrhage The degree of vascularity in thyroiditis varies within a wide range The gland is usually vascular in the acute stage but later on in the chronic stage, when the glandular tissue is destroyed and replaced by poorly vascular and more or less fibrous tissue, the degree of vascularization decreases

The appearance of the contours of the contrast loaded gland seems to be of greater diagnostic value (Fig 5) Thus definitely ragged and unsharp contours were seen only in malignancy A sharp and smooth contour, on the other hand, does not necessarily exclude the possible presence of a small or centrally situated malignant growth A poorly defined contour at the border between the area supplied by the caudal and cranial thyroid arteries is of less significance when the injection has been made selectively into the thyrocervical trunk







Fig 11 Case 5 Nodular colloid goiter The intraglandular branches are stretched and several irregular defects are evident in the lobe but its contour is well defined and even

Fig 12 Case 6 Trabecular adenoma with atypical cells but no invasion of vessel or surrounding tissue Fairly large tortuous and somewhat irregular vessels are present in the arterial phase (left) In a later phase (right) there is marked and somewhat irregular contrast loading of the lobe and some filling of wide veins the lateral contour of the lobe is slightly irregular and not quite distinct

(Fig 8) (Four cases were excluded from the diagram of Fig 5 since the staining of the lobe was too poor to permit a reliable evaluation of the contour)

Early contrast filling of veins is considered an important sign of malignancy in other parts of the body although it may be seen also in other conditions such as inflammation Rapid passage of the contrast medium to the veins in thyroid angiography seems to be of only limited significance It occurred not only in malignant tumours but also in thyroiditis highly vascularized adenomas and particularly in hyperthyreosis

Our findings in the twenty cases of malignant tumours are tabulated in the diagram of Fig 6 The term 'pathologic vessels is widely used in the angiographic literature though rarely well defined The interpretation is essentially subjective and requires skill and experience In the ten cases of the present material where the term was used the vessels had a markedly irregular course and their lumen varied in width (Figs 15 and 17) We prefer to call such vessels atypical in the eight cases in which the changes were less evident Vessels of a similar appearance were present also in one case of trabecular adenoma with atypical cells (Fig 12) and irregular vessels were seen in cases of thyroiditis Pathologic vessels arising from the ascending or superficial cervical artery



Fig 9 Case 3 Recurrent hyperthyreosis Subclavian injection (left) and common carotid artery injection (right) The superior thyroid artery (↔) is wider than the inferior and supplies the major portion of the lobe which already in this phase is opaque



Fig 10 Case 4 Follicular adenoma late arterial phase The contrast staining is well defined but is not as homogeneous as in figs 8 and 9

marked and it appeared earlier than is normal, the main arteries were also wider than in normal cases

The contrast loading was irregular in all but one of the malignant cases (Fig 4), the exception being a poorly vascularized gland The loading in several adenomas was however more or less irregular (Fig 10 and 11) The irregularity probably corresponded to a varying degree of activity within the gland, those parts containing a large amount of colloid being poorly vascularized whereas the more active parts were rich in vessels Avascular areas may of course also be due to necrosis or hemorrhage The degree of vascularity in thyroiditis varies within a wide range The gland is usually vascular in the acute stage but later on in the chronic stage when the glandular tissue is destroyed and replaced by poorly vascular and more or less fibrous tissue, the degree of vascularization decreases

The appearance of the contours of the contrast loaded gland seems to be of greater diagnostic value (Fig 5) Thus, definitely ragged and unsharp contours were seen only in malignancy A sharp and smooth contour, on the other hand, does not necessarily exclude the possible presence of a small or centrally situated malignant growth A poorly defined contour at the border between the area supplied by the caudal and cranial thyroid arteries is of less significance when the injection has been made selectively into the thyrocervical trunk



Fig 14 Case 8 Follicular carcinoma The inferior thyroid artery is wide and gives off an abundance of partly regular branches slightly irregular contrast loading of the lobe and contour not well defined



Fig 15 Case 9 Carcinoma simplex of the thyroid The inferior thyroid artery runs an unusual course and ramifies mainly in the superior mediastinum where numerous tortuous and irregular branches are present

Case 4 (Fig 10) Female aged 64 had noticed a swelling to the right in the neck for about a year There were signs indicating slight hyperthyreosis and increased uptake over the right lobe was seen on scintillography Microscopy of the lobe after removal revealed a follicular adenoma

Case 5 (Fig 11) Female aged 68 with a palpable nodule on the left side which in a year had increased in size the uptake in the scintigram corresponding to the mass was irregular Hemithyroidectomy was performed A nodular goiter partially behind the sternum proved on microscopy to be nodular and rich in colloid

Case 6 (Fig 12) Female aged 71 complaining of pressure symptoms in the neck The right thyroid lobe was somewhat soft and slightly enlarged and a scintigram revealed only a sparse uptake on this side The lobe was removed Microscopy disclosed a trabecular adenoma of somewhat atypical appearances with some degree of variability in the size and shape of the cells and several mitoses

Case 7 (Fig 13) Female aged 64 A pea-sized nodule on the right side on the neck that had been removed in another hospital was microscopically a thyroid carcinoma A hard mass could be palpated on the right side The scintigram disclosed a defect in the uptake corresponding to the upper pole At operation the right lobe was removed and biopsy performed on the left lobe A papillary adenocarcinoma was found in the cranial pole of the right lobe the caudal pole being occupied by a colloid adenoma of walnut size Biopsy of the left lobe revealed normal thyroid tissue

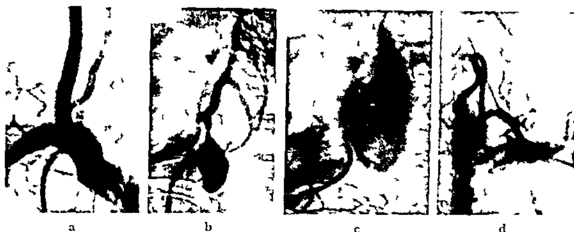


Fig 13 Case 7 Small papillary adenocarcinoma in the superior pole and large colloid adenoma in the inferior Injection into the brachiocephalic trunk (a) and selective injection into the thyrocervical trunk (b) and (c) The intraglandular arteries are much better outlined in (b) than in (a) they are displaced and stretched the loading is more marked and less well defined in the cranial pole (c) corresponding to the small carcinoma than in the caudal part corresponding to the colloid adenoma A normal selective arteriogram of the left side is shown in (d) (confirmed at operation)

could be demonstrated in ten cases (Figs 17 and 18) These vessels, in the diagram of Fig 6, are termed 'extra capsular pathologic vessels The presence of metastases in the lymph glands was confirmed at operation in seven of these cases, in one case, a fibrosarcoma was found close to the thyroid gland, and in the remaining two cases the area was not explored, and confirmation of the extension of the lesion could accordingly not be obtained

Case reports

Case 1 (Fig 7) Male aged 45 with a cerebral tumour which on microscopy appeared to be a metastasis probably from a thyroid carcinoma The right thyroid lobe was slightly enlarged The isotope scintigram was normal On palpation at operation the posterior part of the right lobe was somewhat hard Thyroidectomy was performed but microscopy showed the lobe to be normal apart from a pea sized calcified adenoma in the lower pole

Case 2 (Fig 8) Male aged 45 admitted to hospital because of thyrotoxic signs and symptoms of about two years duration The thyroid was enlarged more on the right than on the left side The scintigram revealed increased uptake over the right lobe where a systolic murmur was also heard Subtotal bilateral thyroidectomy was performed Microscopy revealed hyperplasia of the kind seen in hyperthyreosis

Case 3 (Fig 9) Female aged 21 in whom right side hemithyroidectomy had been performed two years earlier because of signs of hyperthyreosis One year later she had a recurrence and the left lobe had increased in size Subtotal resection was performed on the left side Microscopy revealed diffuse hyperplasia compatible with hyperthyreosis





Fig 17

Fig 18

Fig 17 Case 11 Poorly differentiated carcinoma of the right thyroid lobe with metastases in adjacent lymph nodes Numerous irregular arterial branches are filled from wide branches of the thyrocervical trunk

Fig 18 Case 12 Papillary carcinoma of the right thyroid lobe with extensive extracapsular growth Irregular branches of the wide inferior thyroid artery the ascending and superficial cervical arteries are displaced and also their branches are irregular

Case 12 (Fig 18) Female aged 58 had first noticed a right side goiter two years prior to examination it had gradually increased in size No uptake was evident over the tumour in the scintigram At operation a large tumour fixed to the trachea esophagus and common carotid artery with firm lymph nodes in the vicinity proved microscopically to be a papillary carcinoma

Case 13 (Fig 19) Male aged 61 had noticed a swelling of the neck mainly on the left side for about two months The thyroid was enlarged mostly on the left side firm and not tender No uptake was seen in the scintigram on the left side Left side thyroidectomy and biopsy were performed on the right lobe Microscopy disclosed that the normal thyroid tissue on the left side was completely destroyed by lymphoid tissue A moderate degree of lymphoid hyperplasia was present in the right lobe but most of the thyroid tissue remained intact

Discussion and Conclusions

So far the material is rather limited some types of lesion not being present at all and others being represented by only a few cases It is therefore felt that some caution is necessary in the interpretation of individual cases Generally speaking high activity seems to corroborate fairly well with a high degree of vascularization appearing as contrast loading of a lobe Early and markedly homogeneous staining with rapid filling of the veins for example seems to be characteristic and almost pathognomonic of diffuse goiter with thyrotoxicosis (Graves disease) The number of arteries large enough to be individually distinguished is however not increased Also follicular and parenchymatous



Fig 16 Case 10 Adenocarcinoma of left thyroid lobe Wide inferior thyroid artery inferior medial part of the lobe is vascular and there are small irregular arterial branches superior part is poorly vascularized the arteries in that area being stretched and arched In a later phase (b) the lobe is contrast filled but superiorly the density is less marked

Case 8 (Fig 14) Male aged 68 who for a year had had a right side goiter of gradually increasing size The right thyroid lobe was found to be enlarged and it was firm and elastic The scintigram on this side was irregular The large rather soft tumour that was removed proved to be a follicular carcinoma

Case 9 (Fig 15) Female aged 71 had had a tumour removed from the left side of the neck three years before admission microscopically this proved to be a carcinoma in a lymph node of unknown origin Some time later she noticed increasing swelling in the left cervical region After a second operation when all the lymph nodes on the left side had been removed angiography revealed a tumour in the superior mediastinum This was extirpated and proved to be a carcinoma simplex of the thyroid

Case 10 (Fig 16) Female aged 74 had had a left side goiter of gradually increasing size for two years A hard nodular tumour was palpated No uptake was evident in the scintigram of this area The tumour at operation was found to encroach upon the esophagus and microscopically proved to be an adenoma with malignant changes due partly to adenocarcinoma and partly to anaplastic carcinoma

Case 11 (Fig 17) Male aged 55 had for two years noticed a slowly growing tumour in the right cervical region The growth was attached to the trachea and several lymph nodes could be palpated Following operation the tumour was found to be a carcinoma of low differentiation

apparently depending on the stage The gland may well be vascularized in early cases but in the late stages the normal thyroid tissue may be destroyed and the vascularization poor Different phases may be present in the same gland The angiographic appearances may then be more or less the same as those present in malignant tumours It is hoped that increased experience in the future will enable a differentiation to be made with greater certainty between malignant and inflammatory lesions

A preoperative angiographic study may be helpful in other respects It may be difficult to find the main artery at operation in cases of certain very hard tumours as well as in some cases of thyroiditis A preoperative knowledge of its course and relation to the gland may then be helpful A detailed knowledge of the extension of the tumour, for example in the mediastinum may also be of great value when planning the operation

The present results are generally speaking in accordance with those reported by other authors The material is larger however especially with respect to the number of malignant lesions The diagnostic value of a demonstration of extracapsular growth by vascular supplies from other than thyroid arteries appears moreover to constitute a new approach

SUMMARY

Thyroid angiography was performed in 56 verified cases by the percutaneou. catheter method generally through the axillary artery followed in a fourth of the cases by selective contrast injection into the thyrocervical trunk The angiographic findings in different types of goiter among them 20 malignant cases are described Evidence of extracapsular malignant growth was obtained by the radiographic demonstration of vascular supply deriving from other than the thyroid arteries

ZUSAMMENFASSUNG

Perkutane Katheterangiographie der Schilddruse gewohnlicherweise von der Arteria axillaris aus oder in einem Viertel der Falle durch den Truncus thyreocervicalis wurde in 56 verifizierten Fallen ausgefuhrt Die angiographischen Befunde bei verschiedenen Kropfformen einschliesslich 20 maligner Tumoren werden besprochen Aus der radiologischen Beobachtung dass die Tumoren auch von Arterien die normalerweise nicht die Schilddruse versorgen ihre Blutversorgung erhielten konnte die extrakapsulare Ausbreitung festgestellt werden

RÉSUMÉ

Les auteurs ont fait une angiographie thyroidienne dans 56 cas vérifiés par cathétérisme percutané en général par cathétérisme de l artère axillaire suivi dans certains cas d injection sélective de contrast dans le tronc thyro-cervical Ils décrivent les signes angiographiques dans différents types de goitre parmi lesquels 20 cas de goitres malins L angiographie permet d affirmer l extension extra capsulaire des tumeurs quand elle montre que d autres artères que les arteres thyroidiennes participent à leur vascularisation



Fig. 19. Case 13. Struma lymphomatosa. The narrow left inferior thyroid artery has an irregular kink in its course (a) and in a later phase (b) the contrast loading is low. The loading on the right side is irregular as seen in (c) and (d). (At microscopy the thyroid tissue in the left lobe appeared almost completely destroyed and hyperplasia was present in the right lobe.)

adenomas usually become well filled but the contrast filling is not as homogeneous, probably due to the presence of areas with more distended follicles and areas with regressive changes. In addition, the intraglandular arteries are more arched than normally. The defects in the staining are larger in colloid goiters but otherwise the appearances are about the same. In all the three lesions mentioned, the outer contour of the contrast loaded gland appears sharp and regular.

Malignant tumours are also rich in vessels in spite of the usually low uptake of iodine in the scintigram. The increased vascularity, however, mainly appears as an increased number of arterial branches, running an irregular course. The staining of the tumour is usually uneven and the outlines are ragged and unsharp.

We feel that the angiographic appearances should always be correlated to other findings, for example to clinical signs and symptoms and laboratory examinations. It is thus of special interest to correlate the angiogram with the scintigram since *both of them to some extent reflect the activity of the gland*. Malignant tumours often appear as defects in the latter. The combination of poor uptake in the scintigram and increased vascularity, especially if the vessels are irregular and tortuous, is highly suggestive of malignancy. If in addition arteries in the vicinity, for example the ascending and the superficial cervical arteries, are hypertrophic and give off irregular branches, this is an almost certain sign of a malignant growth spreading outside the capsule.

The angiographic appearances vary considerably in chronic thyroiditis

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ROENTGENOLOGIC APPEARANCES OF TRAUMATIC LESIONS OF MIDDLE MENINGEAL ARTERY

Report of two cases

by

BENGT LILIEQUIST

The meningeal artery and its branches are sometimes injured in fractures of the skull which may lead to traumatic aneurysms or vessel rupture Traumatic aneurysms of the cerebral vessels are rare but appear more often in the middle meningeal artery and its branches than in the cerebral vessels proper The literature records only 15 aneurysms of the meningeal arteries all of which were examined by carotid angiography and verified by subsequent operation and in most cases by histologic examination (AULD ARONSON & GARGANO POUYANNE LEMAN GOT & GOUAZE MARKWALDER & HUBER HIRSCH DAVID & SACHS KIA NOURY SCHULZE DILENGE & WUTHRICH KUHN & KUGLER HOLLAND & THOMSON PAILLAS BONNAL & LAVIEILLE) Most of the aneurysms occurred in combination with epidural hematomas and extravasation of contrast medium during carotid angiography (LINDGREN TIWISINA & STECKER JAMISSON VAUGHAN CRONQVIST & KOHLER LOFSTROM et coll HUBER)

The histologic evidence suggests that all the traumatic aneurysms reported in the literature with the exception of one have been false aneurysms The aneurysm in the case described by AULD ARONSON & GARGANO was furnished with an intima and thus appeared to be a saccular aneurysm of the same kind as those that may appear in the cerebral vessels There was a fracture in the vault and the aneurysm was located on the posterior branch of the

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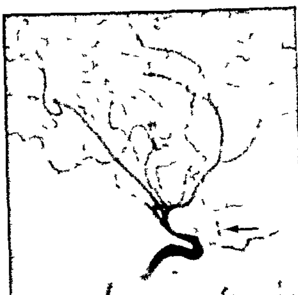


Fig 1 Case 1 Left common carotid angiography lateral subtraction view Irregular aneurysm in the left middle meningeal artery (→) avascular expanding lesion in the middle cranial fossa

parietally it was removed There was no hematoma at the base of the skull but a slight tear of the middle meningeal artery was seen at the site where the extravasation appeared in the roentgen films No aneurysm was evident The patient recovered and no signs of an epidural hematoma nor of an aneurysm of the middle meningeal artery were present at subsequent carotid angiography

Discussion

HASSLER has stated that the walls of the intracranial part of the middle meningeal artery may in some places be conspicuously thin and that media defects are common in these vessels An intimate relationship exists between the dura and the wall of the artery and a traumatic tear in a weakened wall may presumably first appear as an irregular aneurysmal sac which may later be torn to produce a hematoma In most of the cases described in the literature the aneurysm was usually several days old when examined by carotid angiography and had the appearance of a sac which in POUYANNE s case was very large In no case had there been any local clinical signs that could be assigned to an aneurysm the lesions were all found accidentally during carotid angiography

The fate of a traumatic meningeal artery aneurysm is unknown It is generally assumed that such an aneurysm is prone to rupture and produce a epidural hematoma that may prove fatal (MARKWALDER & HUBER) It is

middle meningeal artery directly under the fracture HOLLAND & THOMSON described a meningeal artery aneurysm without any known trauma or fracture of the calvarium. Operation revealed an aneurysm and an epidural hematoma but the histologic investigation provided no evidence of a true aneurysm. In all the other cases reported, a fracture line was present in the vicinity of the aneurysm, and the fracture was usually seen to cross the groove of the meningeal artery. A meningeal artery aneurysm thus seems to appear as a result of cranial trauma. The accompanying bleeding generally produces an epidural hematoma but the bleeding may also be intracerebral (KIA NOURY, POUYANNE et coll.).

HUBER has pointed out that extravasation of contrast medium in epidural hematomas appears within 6 hours following the trauma; this was apparent in all his 12 cases. As the hematoma grows it will probably in itself help to counteract further extravasation. It is however not true that an extravasation of contrast medium necessarily indicates that the medium freely floats into the hematoma; an extravasation is more probably a kind of traumatic aneurysm that subsequently may become thrombosed and healed or transformed into an aneurysmatic sac of more conventional appearance.

Case reports

Case 1. Male, aged 32, suffering from chronic alcoholism and epileptic fits which had increased in frequency during the last year. A fracture in the vault on the right side had been sustained during one of the fits. Severe headache and progressive weakness of both legs developed six days later. The cerebrospinal fluid was tinged with blood, indicating subarachnoidal haemorrhage.

Bilateral carotid and vertebral angiography were performed and disclosed an extracerebral hematoma in the middle cranial fossa on the right side, frontally on the left side and in the posterior fossa, as well as rupture of the left middle meningeal artery and an arterial aneurysm proximally in the left middle meningeal artery (Fig. 1). The patient recovered rapidly. When carotid angiography was repeated, the signs of the extracerebral hematoma as well as the aneurysmatic sac in the left middle meningeal artery had disappeared almost completely. The distal portion of the artery was not filled with medium although the injection was made into the common carotid artery.

Case 2. Male, aged 58, chronic alcoholic, who was found unconscious in the street with clinical signs of injury of the head.

Roentgen examination of the skull revealed multiple fractures with depression on the left side and several fracture lines crossing the groove of the middle meningeal artery. He rapidly developed right sided paralysis and aphasia. Left sided carotid angiography disclosed an epidural hematoma of parietal location, and the distal part of the middle meningeal artery was grossly displaced medially (Fig. 2a). The proximal portion of the artery was markedly irregular and extravasation of contrast medium was evident (Fig. 2b).

Subsequent operation revealed an epidural hematoma apparently of venous origin lying



Fig 1 Case 1 Left common carotid angiography lateral subtraction view Irregular aneurysm in the left middle meningeal artery (→) avascular expanding lesion in the middle cranial fossa

parietally it was removed There was no hematoma at the base of the skull but a slight tear of the middle meningeal artery was seen at the site where the extravasation appeared in the roentgen films No aneurysm was evident The patient recovered and no signs of an epidural hematoma nor of an aneurysm of the middle meningeal artery were present at subsequent carotid angiography

Discussion

Hassler has stated that the walls of the intracranial part of the middle meningeal artery may in some places be conspicuously thin and that media defects are common in these vessels An intimate relationship exists between the dura and the wall of the artery and a traumatic tear in a weakened wall may presumably first appear as an irregular aneurysmal sac which may later be torn to produce a hematoma In most of the cases described in the literature the aneurysm was usually several days old when examined by carotid angiography and had the appearance of a sac which in Pouyanne s case was very large In no case had there been any local clinical signs that could be assigned to an aneurysm the lesions were all found accidentally during carotid angiography

The fate of a traumatic meningeal artery aneurysm is unknown It is generally assumed that such an aneurysm is prone to rupture and produce a



Fig 2 Case 2 Left common carotid angiography a) Oblique view The proximal part of the middle meningeal artery is irregular with extravasation of contrast medium (→) the distal part of the artery is displaced from the vault (←→) by an epidural hematoma b) Lateral view Extravasation of contrast medium along the middle meningeal artery (→)

evident from our Case 1 that a traumatic aneurysm of the middle meningeal artery can also disappear spontaneously, presumably due to thrombosis Another feature of this case was the shape of the anurysm, it was not round but appeared as a *long and irregular formation* In our case, as well as in most of the other cases described in the literature, the films showed the aneurysm to fill later than the cerebral vessels usually do, which is also the case with the meningeal arteries

It is well known that epidural hematomas are sometimes of venous origin, particularly in cases with a protracted clinical course and it is mainly in these that there will be time to perform carotid angiography An extravasation of contrast medium must either be due to passage of the medium into the hematoma, or into a more or less well defined sac or closed space, which may represent a false aneurysm of conventional appearance or a kind of dissecting or fusiform aneurysm that rejoins the artery Such extravasation was present

in Case 2 in combination with an epidural hematoma The hematoma was however not located at the same side as the extravasation of contrast medium, and at operation it was found to be most consistent with a hematoma of venous origin The meningeal artery was not completely severed, a fact that was evident in the roentgen films, the artery was however partly torn at the site of extravasation

It is obvious that the extravasation in this case which roentgenologically had the classical appearance described by many authors, was in fact a sort of traumatic fusiform or dissecting aneurysm This is also consistent with the protracted clinical course, since total rupture of the meningeal artery usually soon leads to a fatal outcome unless operation is performed immediately

Conclusion

A traumatic aneurysm of the meningeal artery may disappear spontaneously, presumably due to thrombosis Its shape may be similar to a conventional aneurysm, i e a more or less rounded sac but it may also be irregular and elongated thus being more like an extravasation of contrast medium along the vessel The angiographically demonstrated similarities in appearance of an aneurysm and extravasation suggest a common etiology Injury to the vessel may probably sometimes cause a well circumscribed aneurysmal sac to appear and in other instances an elongated irregular extravasation of contrast medium may have taken place along the vessel Both processes may be combined with an epidural hematoma not necessarily located at the site of the aneurysm or the extravasation nor need it be of arterial origin Both appear after cranial trauma usually with a fracture adjacent to the course of the injured meningeal artery Both have a more protracted clinical course thus allowing carotid angiography to be performed This procedure is rarely possible with total rupture of the middle meningeal artery which usually causes a brisk and sometimes fatal arterial epidural hematoma The author feels that the two conditions merely represent two aspects of partial rupture of a meningeal artery the extravasation appearing earlier than the aneurysm

SUMMARY

A case of traumatic aneurysm of the middle meningeal artery is described and its connection with extravasation of contrast medium in epidural hematoma is discussed It is suggested that injury to the vessel may cause an early extravasation of contrast medium which later may appear as an arterial aneurysm and finally disappear

ZUSAMMENFASSUNG

Ein Fall von einem traumatischen Aneurysma der Arteria meningealis media wird beschrieben und in Zusammenhang mit Extravasation von Kontrastmittel beim epiduralen Hamatom besprochen. Es wird angenommen, dass eine Gefassverletzung zuerst eine Extravasation verursacht, die spater als ein Aneurysma erscheint und danach vollig verschwindet.

RÉSUMÉ

L'auteur décrit un cas d'anévrisme traumatique de l'artère méningée moyenne et examine ses relations avec l'extravasation de moyen de contraste dans un hématome extradural. Il pense que la lésion du vaisseau peut donner lieu à une extravasation précoce de moyen de contraste qui par la suite peut avoir l'aspect d'un anévrisme artériel et finalement disparaît.

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ELECTROCARDIOGRAMS IN CAROTID ANGIOGRAPHY WITH UROGRAFIN

by

HERMAN LODIN and HANS GEORG OTTANDER

Reports on experimental as well as clinical investigations on the influence of modern contrast media upon the electrocardiogram in carotid angiography have been published Sodium acetrizoate (Triurol), sodium diatrizoate (Hypaque) and sodium diprotrizoate (Miokon) were investigated experimentally among others by LINDGREN (1959) KÅGSTROM et coll (1960) and TORNELL (1963) Their investigations indicate that contrast media of the acetrizoate type are more toxic (they cause for example more marked changes in the electrocardiogram) than the representatives of the two other types Of these two last mentioned types the media belonging to the diatrizoate group seem to be less toxic

The clinical effect of the contrast media was described by GREITZ in 1956 (Triurol) EPSTEIN et coll in 1959 (Hypaque) GREITZ & WEISS in 1959 (Hypaque and Miokon) and KLINGLER in 1960 (Urografin) SJOGREN (quoted by TORNELL) found that the tendency towards bradycardia was less after sodium diatrizoate than after sodium acetrizoate and that a mixture of the methylglucamine and sodium salts (Urografin) produced less bradycardia

Submitted for publication 5 April 1966

Table I

Comparison between different contrast media in relation to changes observed in the electrocardiogram by various authors

Authors	GREITZ	EPSTEIN et coll	GREITZ & WEISS	KLINGLER	Present material
Contrast medium	*Triurol*	*Hypaque*	*Hypaque* Miokon	Urografin	Urografin
Number of patients injected	57	20—30	7	22	150
Number of injections	100	30	24	49	600
ECG changes	%	%	%	%	
No change	7	30	29	73	41
Bradycardia	65	70	46	18	31
Tachycardia	13		25	9	17
Marked changes	15				
Indefinite slight changes					11

than the pure sodium salt (Hypaque). The results as well as the extent of the clinical investigations are apparent from Table 1. The materials in which diatrizoate was used are small and the results may not give a true representation of the effect of the contrast medium. The authors therefore believe that a report upon the changes in the electrocardiogram in a more extensive material may be justified.

Material and Method. The material comprises 150 patients, nearly all of whom were premedicated in the same way (1 ml morphine scopolamine). The puncture was generally made low down in the common carotid artery, less often in the internal carotid artery, and always more than 1 cm from the carotid sinus. About 6 ml Urografin 60 % were injected automatically, at least four injections being given to each patient, i.e. more than 600 injections in the whole series. Each investigation was initiated with a roentgenogram of the puncture area to control the position of the needle. The electrocardiogram was registered in lead II, before, during, and 20 to 30 sec after the injection and the changes observed were described as 'bradycardia', 'tachycardia' and 'indefinite changes'. Alterations in the heart rate exceeding 10 % were recorded as signs of bradycardia or tachycardia. Unimportant changes in rhythm without settled tendency, e.g. slight bradycardia at one injection and slight tachycardia at another, were registered under the heading of 'indefinite changes'.

Table 2

ECG changes observed in the material grouped according to age and sex

ECG changes	(1 0)	Males (65)	Females (85)	40 years and over (112)	< 40 years (38)
No change	62	22	40	46	16
Bradycardia	46	20	26	35	11
Tachycardia	26	14	12	21	5
Indefinite slight changes	16	9	7	10	6

Results

The percentage distribution of the ECG changes observed in the present material in comparison with the material of other authors may be seen in Table 1 In Table 2 the sex and age distribution are recorded The material also includes nine double sided examinations in seven of which the ECG changes were of a similar nature while in two of them divergent results were obtained Occasional extrasystoles were recorded on injection in 9 patients but there were no signs of asystole (> 2 seconds between the heart beats) or of myocardiac affection The bradycardia was often followed by slight tachycardia The age distribution produced nothing of interest The women had a greater tendency to unchanged ECG than the men who responded to a higher degree with tachycardia

Discussion

The marked difference between the acetrizoate and diatrizoate types of media are evident from Table I Only 7 % of the Triurol injections produced an unaffected electrocardiogram compared to 41 % of the Urografin injection (present material) No serious ECG changes like those observed in 15 % of cases by GREITZ were noted EPSTEIN s rather small material (Hypaque) was characterized by the fact that only bradycardia was registered as a subsidiary effect probably due to the small size of the material GREITZ & WEISS however recorded tachycardia effects in their small material with the same kind of contrast medium KLINGLER reported no ECG changes in 73 % of his cases (Urografin) a larger percentage than in the present material but then the former also refers to a small series

GREITZ among others stated that the bradycardia and tachycardia effects were probably caused by the influence of the contrast medium on the vaso motor centres of the brain and thus that they should be independent of wheth

er the injection site was above or below the carotid sinus. This author moreover was not able to demonstrate any increase in pressure within the carotid artery during the injection, which might have stimulated the baroceptors in the carotid sinus and explain the bradycardia effect. An automatic syringe and probably higher injection pressure than in GREITZ's material were used in the present series. If an elevation of the intracarotid pressure were of any essential importance, the frequency of bradycardia changes would not be as low as those in the present material.

All punctures are made at a distance of more than 1 cm from the carotid sinus either into the common or the internal carotid artery. The present authors, like GREITZ, found the same bradycardia influence independently of the injection site, even as far as 10 cm from the sinus region in one case. That in this case a stretching effect on the vessel wall could have acted as stimulator of the baroceptors therefore seems improbable.

The present investigation thus lends support to the statement made by GREITZ. The ECG changes are mainly due to a central influence. A reservation is however made for the injection effect when the puncture is made into the sinus itself, the problems involved with such an event will be dealt with in another publication (LODIN). Yet, the central influence of the contrast medium is not one and the same, because bradycardia as well as tachycardia effects may be observed. These may depend on individual variations in the vascularization of the vasomotor centres or different local reactions to the contrast medium.

The results obtained and the comparison made with previous investigations, in which other kinds of contrast were also used, indicate the relatively slight toxicity of Urografin. Nearly half the number of electrocardiograms were unaffected and less than a third of the patients had a bradycardia effect. More serious changes of the asystole type were not demonstrated, nine patients had isolated extrasystoles.

SUMMARY

A report on a material comprising 150 carotid angiographies representing more than 600 contrast medium injections of Urografin is presented. No ECG changes were recorded in nearly half the number of cases and bradycardia in less than a third.

ZUSAMMENFASSUNG

Es wird über 150 Karotisangiographien mit insgesamt 600 Kontrastmitteleinspritzungen von Urografin berichtet. In beinahe der Hälfte von den Fällen wurden keine elektrokardiographischen Veränderungen registriert und in weniger als ein Drittel der Fälle wurde Bradykardie observiert.

RÉSUMÉ

Les auteurs presentent une série de 150 angiographies carotidiennes représentant plus de 500 injections d Urografin Dans près de la moitié des cas l ECG n a pas été modifié On a observé une bracycardie chez moins du tiers des sujets

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MYELOGRAPHIC APPEARANCES OF DISK PROTRUSIONS IN DIFFERENT POSITIONS

by

ANDERS MOVIN

Myelography with a water soluble contrast medium has long been the method of choice for investigating changes in the lumbar intervertebral disks causing protrusion into the spinal canal The procedure most commonly used has been that introduced by ARNELL (1944, 1948) and subsequently modified by LINDBLOM (1946) and by VAN DER WERFF (1948) in which the patient is recumbent and the films are taken in different projections WORINGER & LANGS (1948) began to examine patients in the sitting position, and since then WORINGER and his co workers (1950 1955 1956) have published reports on 600 cases in which *myelography with a water-soluble medium had been carried out with the* patient upright They argue that a herniation is likely to increase in size when a patient is sitting up, and hence should be more easily detected They also mention the clinical observation that a patient with a ruptured disk often experiences greater discomfort when in the upright position than when lying down Comparative myelographic studies in the same patient in both upright and recumbent positions were not undertaken

Myelography *with a water soluble contrast medium* and with the patient recumbent was also carried out by DE SEZE et coll (1948 1949), who found that

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an increased degree of lordosis produces increased deformation of the sub arachnoid space KNUTSSON (1942), who examined patients both upright and recumb nt demonstrated that lordosis causes increased bulging of the inter vertebral disks into the subarachnoid space The possibility that the upright position as such might affect the size of a ruptured or protruding disk was not discussed

The purpose of the present investigation was to study the influence of the upright position as well as the part played by the lordosis as regards the size of disk lesions protruding into the subarachnoid space All the patients were examined first in the recumbent position and then, immediately afterwards upright

Examination in the recumbent position The patient lies on his side and the foot of the table is tilted 10° downwards The spinal column is placed parallel to the edge of the table with the aid of pillows After puncture of the spinal canal anaesthesia is produced with 0 8 to 0 9 ml xylocain 5 % (lidocaine NFN) The blood pressure is kept under continuous observation and ephedrine in a dose corresponding to 1 ml/75 kg body weight is injected intramuscularly as a routine measure to prevent a fall in pressure

Approximately 5 minutes after administration of the anaesthetic 15 ml Contras U 20 % (Leo) are injected and a p views are obtained The patient is thereafter turned 10 25 and 45 degrees towards prone position and films in these positions are produced Finally a lateral film is obtained with the patient prone All these roentgenograms are obtained with the beam horizontal

Examination in the upright position After the recumbent examination has been completed the table is raised to the vertical position and the patient is placed on a bicycle seat fastened to the table Three films are taken a straight a p view an oblique view with the side to be examined turned 25 degrees backwards and a lateral view

Results

A total of 46 patients with signs suggestive of rhizopathy were examined both recumbent and erect and any intervertebral disk lesions bulging into the spinal canal were compared in the two positions Definite lesions were demonstrated in 35 instances They were mainly of two different types One group consisted of characteristic disk ruptures with swollen nerve roots often in combination with defective filling of the corresponding root sleeve in most of these patients the affected nerve root was displaced as well The other group consisted of changes



Fig 1 Disk rupture in a patient examined in both recumbent (a) and erect (b) positions The radiographic appearances are the same in both views

Fig 2 Disk rupture oblique views recumbent (a) and erect (b) The herniation bulges farther in towards the spinal canal with the patient erect and the curvature is greater

in which the disk was protruding directly towards the dorsal aspect, without any demonstrable alteration of the nerve roots or root sleeves

Disk ruptures Myelographic features characteristic of disk rupture were seen in 15 patients, and surgical intervention in fourteen of them confirmed the presence of a ruptured disk In 14 of the 15 patients it could not be decided with certainty whether the herniation differed in size in the two positions (Fig 1) It should be remembered, however that it is always difficult to achieve an exact repetition of the oblique projection, which is the one in which a disk rupture is most clearly seen In one patient the herniation into the subarachnoid space appeared much larger in the film obtained in the upright position the degree of lordosis was much greater in the upright than in the recumbent position (Fig 2)

Disk protrusions Dorsal protrusion of the disk without alteration of the nerves was present in 20 patients In ten of these the protrusion differed in size in the upright and recumbent films in seven it was larger in the erect and in three patients it was larger in the recumbent view In one of these ten patients it was not possible to establish any difference in the degree of lordosis the protrusion was largest in the upright position In the other nine patients, the protrusion was always largest in the view in which the curvature was greatest, irrespective of whether the patient was recumbent or upright (Figs 3 and 4)

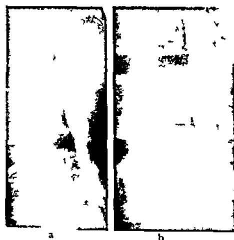


Fig 3 Disk protrusion lateral views When the patient was in the erect position (b) the protrusion as well as the curvature appeared greater than in the recumbent position (a)

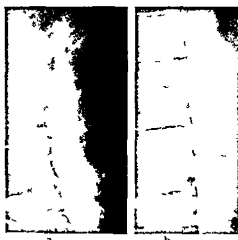


Fig 4 Disk protrusion lateral views The protrusion increased and became visible in conjunction with an increase in the curvature in the recumbent position (a) as compared to the erect position (b)

In one out of 15 patients with characteristic disk rupture the hermation was larger in films taken in the upright position the degree of curvature also being increased In ten out of the 20 patients with disk protrusion the size of the lesion differed in the recumbent and upright views being larger sometimes in the one position sometimes in the other, in nine of these ten patients the protrusion was largest when the degree of lordosis was greatest To judge from these results the position of the body as such is not of decisive importance in the myelographic assessment of the size of a prolapsed disk the lumbar curvature would seem to be of greater significance

SUMMARY

Myelography was carried out in 46 patients recumbent and upright with a view to comparing the size of disk lesions in the two positions The degree of lumbar curvature not the position of the body as such would seem to be the important factor in determining the myelographic appearances of disk lesions

ZUSAMMENFASSUNG

An 46 Patienten wurde Myelographie in liegender und sitzender Stellung vorgenommen um die Grosse der Scheibenlasion in den zwei Positionen zu vergleichen Es zeigte sich dass der Grad der Lordose fur die myelographischen Erscheinungen der Lasionen ausschlaggeben der war als die Lage des Korpers

RESUME

Des myelographies ont ete faites chez 46 malades assises et couches pour comparer les dimensions des lesions discales dans ces deux positions Il semble que ce soit le degre de courbure lombaire et non la position du corps elle meme qui constitue le facteur important de l aspect myelographique des lesions discales

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ARTERIAL GEODESICS AND TEMPORAL TUMORS

by

HAROLD Z LEHRER

Displacements of convexity arteries by intracranial mass lesions may be direct (tangential) or indirect (non tangential) In direct or tangential displacements the arteries are usually markedly curved and tend to approximate the outlines of the tumor with which they are more or less in contact This is the typical radiographic picture of arteries in the vicinity of an extra axial tumor such as meningioma.

Intra axial tumors on the other hand tend to show arteries which are less highly curved in their neighborhood These indirect non tangential displacements are generally secondary to the underlying volume expansion rather than to the direct effect of the tumor itself and the displaced arteries do not tend to outline the tumor contours Because of the increase in volume convexity vessels stretch and tend to assume shortest distance paths between points of relative attachment or constraint Mathematically the shortest distance paths over a surface are known as geodesics

Geodesics of the Euclidean plane are straight lines but for the surface of a sphere like the earth geodesics are great circles Thus since tumor expansion tends to be spherical over the cerebral convexity intra axial tumors stretch adjacent convexity arteries into great circles which have been called tumor meridians (LEHRER 1967)

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Fig 1 Illustration of indirect arterial displacements with volume expansion Two rubber bands are fixed on a balloon model at three points with slack or redundancy between points of attachment simulating convexity arteries As the volume of the balloon increases the slack is taken up and the rubber bands stretch *tending to follow shortest distance paths or geodesics* between points of constraint Over a sphere they will ultimately form great circles (tumor meridians) convex to each other

The mechanism of indirect displacement secondary to a spherical volume expansion is illustrated in Fig 1 by showing the changes in configuration of rubber bands over the surface of a balloon with increasing volume

When an intra axial mass increases the volume of the temporal lobe, its surface arteries also tend to form shortest distance paths between points of constraint However, the configuration of the resultant geodesics differs from those over the convexity since the temporal lobe surface will generally tend to resemble a flattened ellipsoid or, occasionally a cylinder, rather than a sphere Also, there are special anatomical constraints due to the presence of the Sylvan fissure and insula

Temporal lobe anatomy in relation to arterial displacements The middle cerebral artery generally *subdivides to send two or three main branches to the* insula In adults, these normally lie approximately one centimeter or less anterior to and above the clinoparietal line In children they are up to two centimeters from the line (CHASE & TAVERAS 1963 TAVERAS & Wood 1965) The main middle cerebral *branches subdivide in turn to supply the insula* and the fronto parietal convexity as well as to send approximately three branches the superior, middle and inferior temporal arteries, over the surface of the temporal lobe

The main branches of the middle cerebral artery lie deep between sulci of the Sylvian fissure and the insula For the major portion of their course they are overlain by the temporal lobe and they are confined medially The secondary branches over the surface of the temporal lobe posterolateral to the insula, on

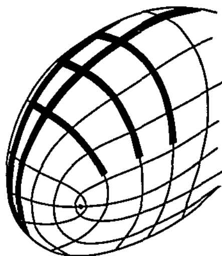


Fig 2 Geodesics of the temporal tumor ellipsoid When it expands as the result of an intra axial mass lesion the temporal lobe surface tends to be ellipsoidal rather than spherical Geodesics of an ellipsoid form families of approximately parallel curves as shown with one family running longitudinally and the other transversely Main insular branches follow the upper border along longitudinal geodesics because of anatomic constraints They are portrayed by thick lines as are some members of the transverse geodesic family The latter have been accented for illustrative purposes but in patients surface arteries may instead follow the longitudinal family or a somewhat mixed course



a



b

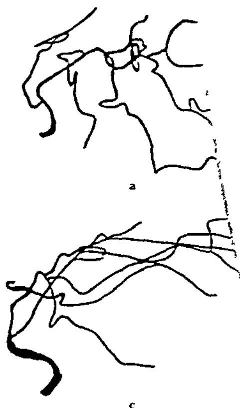


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d

Fig 3 Examples of art ri l geodesics in pat ents with intra axial temporal mass lesions glioblastoma (a) hematoma (b) metastatic carcinoma (c) and carc noma (d) In (b) (c) and (d) arterial geode ics tend to follow the trans erse family as seen in f g 2 A mixture of transverse and longitud nal geodesics appear in (a) with one artery changing its course afte beginn ng trans ersely to p oceed longitud nally





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Fig 4 Further examples of arterial geode
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Temporal tumor ellipsoid and ar

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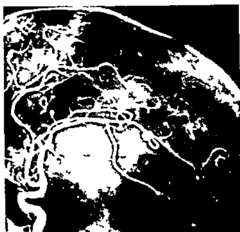


Fig 5 Lateral arteriogram corresponding to fig 3a Arterial geodesics as seen in the context of the arteriogram At operation a glioma with two ragged cysts was found in the anterior aspect of the left temporal lobe Histologically some areas resembled fibrosarcoma One surface artery after beginning transversely bends to proceed longitudinally



Fig 6 Lateral arteriogram corresponding to fig 3d performed because the patient showed personality changes right hemiparesis and aphasia Glioblastoma was found in the temporal lobe at craniotomy Arterial geodesics follow the transverse family

tumor ellipsoid is shown in Fig 2 adapted from HILBERT & COHN VOSSEN (1952) Two families of geodesics one transverse and the other longitudinal are depicted The main middle cerebral branches always belong to the longitudinal family since they are confined anatomically while surface branches tend to follow either the longitudinal or transverse family of geodesics in the lateral arteriograms of patients with intra axial temporal tumors (Figs 3 to 6)

Within each family geodesics over the less curved portions of the ellipsoid are approximately parallel Mathematically since a parallelogram can be decomposed into two triangles this is related to the theorem of Gauss that the difference between the sum of the angles of a geodesic triangle and 180 degrees equals the total curvature of the area enclosed by the triangle (DARBOUX 1894) A cylinder can be unrolled into the Euclidean plane hence it is a surface of zero curvature (HILBERT & COHN VOSSEN 1952) and its geometry is the familiar one of Euclid with straight line geodesics 180 degree triangles and exactly parallel lines

One can reason backwards and from the course of the arterial geodesics infer the shape of the temporal lobe surface under the influence of the tumor volume increase Occasionally divergent convex arterial arcs around a central tumor meridian may be seen indicating a locally spherical surface However in general



Fig 4 Further examples of arterial geodesics in patients with intra axial temporal mass lesions malignant tumor of unclassified histologic type (a) glioblastoma (b) glioblastoma (c) and astrocytoma (d) There remains some slack in the surface arteries over the temporal lobe in (a) which otherwise can be recognized as forming geodesics of the transverse family Arterial geodesics tend to follow the longitudinal family in (b) and (c) In example (d) from a child of 6 years the essentially transverse geodesics are situated more posteriorly

the other hand, are freer to respond to tumor volume displacements Thus the major insula branches outline the anterosuperior border of the temporal lobe while smaller surface arteries tend to form geodesics as the volume of the temporal lobe increases Since secondary temporal arteries double upon them selves to a variable extent within the insula before emerging from it there may be varying amounts of 'slack available to be taken up before the arterial geodesics become readily apparent

Temporal tumor ellipsoid and arterial geodesics

The outer surface of the temporal lobe is flatter and longer than the more nearly spherical convexity As its sulci are smoothed out by an intra axial tumor mass, its surface is approximated by that of an ellipsoid with its long axis anteroposterior and its shortest axis between the insula and calvarium Such a



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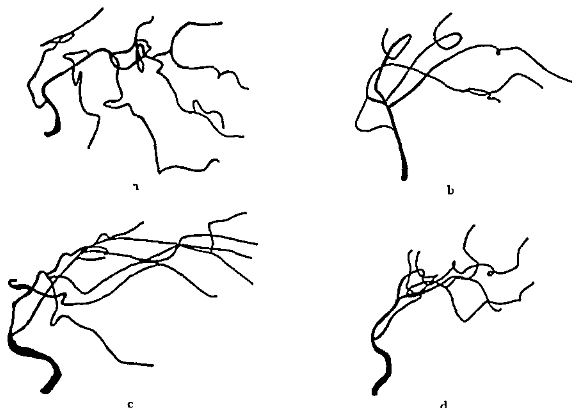


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The outer surface of the *temporal lobe is flatter and longer than the more* nearly spherical convexity As its sulci are smoothed out by an intra axial tumor mass, its surface is approximated by that of an ellipsoid with its long axis anteroposterior and its shortest axis between the insula and calvarium Such a

tumors unless medially situated simply elevate the temporal branches along with the temporal lobe In their terminology, arterial geodesics were referred to as draping of temporal branches

The term draping is ambiguous in this context because by a peculiarity of the English language two of its common meanings are contradictory here Webster s Second International Dictionary gives one meaning of drape as to cover or adorn with drapery or folds of cloth, as to drape a bust a building etc which coincides with the sense intended However the other meaning to hang in loose folds suggestive of drapery (see Fig 8) is exactly opposite here and applies better to the arterial changes with extra axial tumors

SUMMARY

In the presence of intra axial temporal tumors the major middle cerebral insular arteries outline the temporal lobe border and the branches tend to become geodesics of the temporal lobe surface These arterial geodesics run approximately parallel and are generally less convex than are the geodesics in cases of convexity tumors thus reflecting the lesser mathematical curvature of the outer surface of the temporal lobe in comparison with the convexity The term draping when used to describe arterial geodesics is ambiguous

ZUSAMMENFASSUNG

Bei intra axialen temporalen Tumoren wird der Schlafenlappenrand von der insularen Ar teria cerebralis media umrissen und die Äste werden als geodatische Linien auf der Ober flache des Schlafenlappens erscheinen. Diese arterielle geodatische Linien laufen ungefahr parallel und sind meistens weniger konvex als in Fallen von Konvexitatstumoren Sie wider spiegeln also die geringere mathematische Kurvatur der Oberflacke des Schlafenlappens im Vergleich zu anderen Teilen der Konvexitat In diesem Zusammenhang ist der Ausdruck draping nicht eindeutig

RÉSUMÉ

Dans les cas de tumeur temporale intra axiale les principales arteres insulaires de la cerebrale moyenne dessinent le bord du lobe temporal et les branches tendent a devenir des lignes geodesiques de la surface du lobe temporal Ces geodesiques artérielles ont des trajets à peu pres paralleles et sont en general moins convexes que les geodesiques dans le cas de tumeur de la convexite refletant ainsi la moindre courbure mathematique de la surface externe du lobe temporal par comparaison a la convexite Le terme de drapé utilise pour decrire les geodésiques arterielles est ambigu

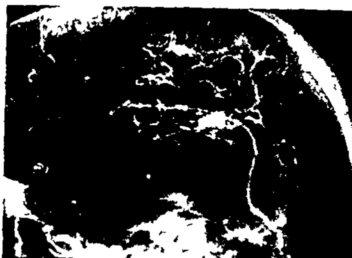


Fig 7 Geodesics of a nearly cylindrical surface *Arterio-venous* malformation in the upper Sylvian region with an early superficial draining vein posteriorly Middle cerebral main branches are markedly elevated the surface branches are of very fine caliber (due to spasm) as they run almost exactly parallel over the temporal lobe indicating a virtually cylindrical surface At operation a large *temporal* lobe hematoma was evacuated

temporal arterial geodesics will be more parallel, approximately *conforming to a* family of geodesics over an ellipsoidal surface In one of our cases rapid expansion of the temporal lobe occurred because of *an intracerebral bleed from* an arteriovenous malformation (Fig 7) The resultant family of arterial geodesics was *almost exactly* parallel indicating that the expanded temporal lobe had formed a virtually cylindrical surface

In *reviewing 118* cases of intra axial temporal tumor CHASE & TAVERAS (1963) found arterial geodesics in all but one case By contrast extra axial



Fig 8 The second meaning of draping Detail from the painting Madonna and Child with Saints Peter and Sebastian by BELLINI in the Collection of Italian paintings in the Louvre The folds of drapery hang loosely as they are lifted from below

FROM THE DEPARTMENT OF RADIOLOGY AND INTERNAL MEDICINE (DIRECTOR DOCENT ROMAN MARCINIAK), THE MEDICAL ACADEMY OF WROCLAW POLAND

RADIOLOGIC STUDIES OF THE GASTRO-ESOPHAGEAL VESTIBULE IN NORMAL AND PATHOLOGIC STATES

by

ROMAN MARCINIAK

The gastro esophageal vestibule the so called sphincter area or pressure barrier between the stomach and the esophagus is still the object of much attention in the literature The number of different terms proposed for this part of the esophagus mirrors the controversial and incomplete state of knowledge concerning its anatomical structure and physiologic function The term gastro esophageal vestibule introduced by LERCHE (1950) has been accepted by the present author and seems to be the one most commonly used for this part of the lower esophagus The radiologic term empty segment also appears justified since in the inspiratory phase the region is devoid of barium Manometric esophageal pressure studies have revealed that the vestibule may be the site of elevated pressure it is therefore also known as the high pressure zone or pressure barrier between the stomach and the esophagus

The gastro esophageal vestibule is a constant roentgen finding in every normal subject Its length as reported in the literature is between 2 and 5 cm and it is situated between the phrenic ampulla and the cardia (see Fig 1)

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WEBSTER'S NEW INTERNATIONAL DICTIONARY Second edition Unabridged Merriam Co Springfield Mass 1942



Fig 2 Measurement of the vestibular length was performed on four spot film of the esophagus obtained in prone position during free swallowing of the barium (a) in full inspiration (b) with the breath held (c) and in full expiration (d)

accurate to within 0 1 mm The average value of four such measurements was accepted as the vestibular length in each subject Attention was paid to the shape and development of the phrenic ampulla and distinction was made between non developed slightly developed and well developed ampullas

Results

Group of normal controls This group consisted of 160 males in ages between 16 and 28 years 89 of whom were in the second decade of life and 71 in the third

In the phase of inspiration and when the breath was held the gastro esophageal vestibule always appeared as an empty segment During free swallowing of barium and in the expiration phase the vestibule appeared as a narrow space in some instances evidently narrowed The outlines of the vestibule were clear cut and the longitudinal mucosal folds could be traced Gastro esophageal reflux was never seen

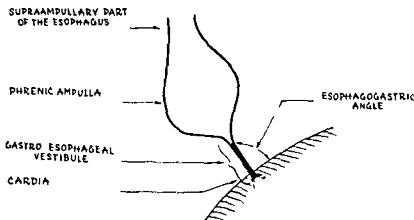


Fig 1 Schematic illustration of the lower esophageal region

The purpose of the present paper is to present a method of mensuration of the vestibule, on roentgenograms and briefly to describe the appearances of the vestibule, in particular examinations and respiratory phases, as resulting from examinations of patients and normal subject in different age groups On the basis of the data obtained, the average length of the vestibule in each group has been determined, and the changes occurring in various disorders, excluding those primarily confined to the esophagus, have been studied An attempt has also been made to ascertain whether a relationship existed between the length of the vestibule and the appearance and development of the phrenic ampulla, with due reference to the type of stomach investigated

Material and Method The material consisted of 800 patients of both sexes, in ages between 16 and 78 years, with various gastro intestinal symptoms, excluding those referable to the esophagus In addition, 160 healthy young males served as a control group

The examinations were performed with the subject prone and turned slightly to the left towards the roentgen screen so as to get the esophagus projected behind the spine The focus film distance was 1 meter Four films were obtained (1) during free swallowing of the barium emulsion (2) in full inspiration, (3) with the breath held, and (4) in full expiration (see Fig 2) In the beginning, in some instances, the subjects were also examined erect The information then obtained was however found to be of small value therefore, with due regard to radiation hazards it was not considered warranted to include such films in the study

The shape and length of the gastro esophageal vestibule were estimated from the roentgenograms obtained The vestibular measurements were taken twice for each exposure and measured separately on each film with callipers

Table 2

Major symptoms and clinical diagnosis in 676 patients subjected to roentgen examination of the gastro intestinal tract

Condition	Number of patients
Gastric ulceration	142
Duodenal ulceration	170
Gallstones	92
Cholecystitis	78
Gastric neoplasm	84
Ulcerative colitis	54
Pancreatic diseases	28
Other abdominal disorders	28

was 3 3 cm while in the 62 subjects with a well developed ampulla it was 3 1 cm These observations indicate a lack of correlation between the degree of phrenic ampulla formation and the length of the vestibule

Group of patients with various disorders In the material of 800 patients the vestibule could be measured in 676 (see Table 1) The patients had been roentgen examined for various abdominal disorders mostly for gastric and duodenal ulcers biliary tract conditions and ulcerative colitis (Table 2)

The roentgenographic appearance of the vestibule in the different respiratory phases and at various degrees of contrast filling did not vary in comparison with the control group

The vestibule was longest in the inspiratory phase seen as an empty segment and the difference in length between the inspiratory and expiratory phases varied between 3 and 5 mm No gastro esophageal reflux was observed with the examination method applied As was the case in the group of controls no evident relationship could be established between the length of the vestibule and the body height of the subjects

Particular attention was paid to the possibility of observing any relationship between the length of the vestibule and the presence of different gastro intestinal diseases, or other abdominal disorder Within the same age groups the vestibular length did not vary in gastric or duodenal ulceration as compared with observations made in biliary disorders or other abdominal conditions It could usually be discerned whether the phrenic ampulla was slightly or well developed Again as in the controls no relationship could be

Table 1

Average length of the gastro esophageal vestibule in consecutive life decades in a material of 676 patients

Life decade	Males	Females	Together	Average length of vestibule
II	21	15	36	3.1 cm
III	18	62	80	3.0 cm
IV	48	42	90	2.8 cm
V	43	72	115	2.9 cm
VI	115	92	207	2.4 cm
VII	48	52	100	2.4 cm
VIII	27	21	48	2.0 cm

It was possible to measure the vestibular length in 123 of the subjects in the majority of them it represented the length of the space between the ampulla and the cardia The lower end of the phrenic ampulla appeared as a tapering of the esophageal contour When the ampulla was not clearly developed a step like narrowing of the esophageal contour was accepted as the upper end of the vestibule The cardia was easily recognized as a rosette formation of the gastric mucosal folds

The values obtained for the gastro esophageal vestibule were 3.3 cm for the group in the second, and 3.1 cm for the group in the third decade of life The vestibule appeared longer in inspiration and shorter in full expiration The difference between these phases amounted to between 3 and 4 mm

No relationship could be established between the vestibular length and the body height of the subjects examined Extremes of high or low values (bottom value = 2.0 cm and top value = 5.2 cm) were observed, irrespective of the body height of the subjects Thus, in both decades of life, the vestibule measured more than 4 cm in some subjects who were between 160 and 165 cm in body height while it was less than 3.0 cm in some who were between 180 and 184 cm tall

No correlation was evident between type of stomach (hypertonic or orthotonic) and the length of the vestibule

A phrenic ampulla was present in 126 of the controls the ampulla was slightly developed in 64 and well developed in 62 of these In the remaining 34 subjects of the control group the ampulla could not be demonstrated, the average length of the vestibule in this group was 2.9 cm In the group of 64 subjects with a slightly developed ampulla, the average vestibular length

the length of the vestibule and it could clearly be separated from neighbouring structures This is contrary to statements made by POPPEL et coll (1955) and by BIVETTI (1960) According to these authors the junction between the phrenic ampulla and the vestibule can seldom be established radiologically

We could find no reports on the radiologic measurement of the length of the vestibule in our review of the literature In studies reported on the mano metric recording of the intra esophageal pressure the vestibule has been mentioned as a high pressure zone measuring between 2 and 5 cm depending on the method used, on the technique of examination and the material When the length of the vestibule is given in the radiologic literature it has been deri ved from such manometric studies or from post mortem examinations The length of the vestibule has been reported to vary between 2 cm and 1/8 of the whole esophageal length thus BOTHA (1962) 1 2 to 2 cm JOHNSTONE (1959) 2 to 3 cm BROMBART (1961) 3 to 5 cm, SANCHEZ et coll (1953) 1/8 of the whole esophageal length IMDAHL et coll (1962) 4 to 5 cm

There were no reports to be found in the literature concerning variations in length of the vestibule in particular age groups in adolescence and old age for instance

The control group in our investigation was represented only by males due to the easy accessibility of these subjects but this does not seem to detract from the value of the results obtained BOTHA stated that the anatomical as well as the physiologic conditions in the lower esophagus are the same irrespec tive of sex The values in our control group compared to those of the correspond ing age in the disease group revealed no significant differences Extension of the examinations to controls of more advanced ages was therefore postponed

Our examinations in the second group were performed in patients of both sexes in ages over 20 years and with various extra esophageal abdominal disorders (see Fig 3)

It was established from the measurements performed in this group of pa- tients that the vestibular length slightly diminishes with age This fact may be explained by the involution that takes place in the esophagus at progressing age in the same manner as occurs with other internal organs which results in shortening of the pressure barrier between the esophagus and the stomach

We believe to have established that extra esophageal abdominal disorders have no influence on the length of the vestibule and that the number of measurements performed (676) are sufficient to allow the conclusion that the gastro-esophageal vestibule is not changed by any visceral reflex mechanism in biliary or other abdominal disorders This may constitute evidence of the stability of the esophago-gastric closing mechanism and of its resistance to stimuli from other abdominal organs

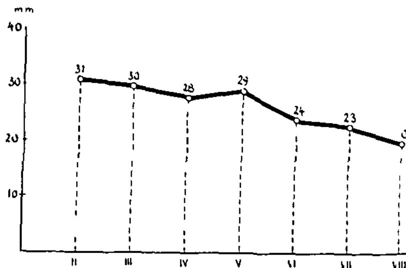


Fig 3 The average length of the gastro esophageal vestibule as derived from examinations of 676 patients in different age groups (decades of life)

established between the degree of development of the ampulla and the length of the vestibule

Discussion

The radiologically established presence of a gastro esophageal vestibule, as a composite structure of the esophageal sphincter, may be regarded as evidence of the normal functioning of the closing mechanism of the lower part of the esophagus Failure to demonstrate the vestibule may be due to organic lesions or functional disorders in the lower esophageal region, or it may be due to a technically unsatisfactory examination

It seems to have been clearly demonstrated in the present investigation by means of conventional radiography of the lower esophageal region that a gastro esophageal vestibule is present in the majority of individuals It could be observed in 123 of the 160 subjects belonging to the control group and in 676 of the 800 patients in the group of various disorders In the remaining subjects of both groups it was the poor technical quality of the roentgen films that prevented definition of the vestibule

Certain parts of the gastro esophageal vestibule namely its supra and infradiaphragmatic portions, could not be demonstrated with conventional radiography in the present material Measurement of these parts by means of cinefluorographic examinations (Bivetti 1960, Buchheim & Maurer 1961) has also failed, only in a few cases could the supra and infradiaphragmatic parts of the vestibule be seen and measured

It was however possible in most cases in the present investigation to measure

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SIGNIFICANCE OF COURSE OF LIGAMENTUM TERES HEPATIS IN DIAGNOSIS OF SPACE-OCCUPYING LESIONS NEAR THE LIVER HILUM

by

B GRUMSTEDT and L WAHLQVIST

Preoperative investigation of a 37 year old woman with carcinoma of the duodenojejunal flexure included selective angiography of the coeliac trunk Some branches of the common hepatic artery and intrahepatic portal vein were observed to run an arched course thought to be due to the probable presence of secondary deposits but the intestinal tumour was nevertheless excised Palpation of the liver revealed no evidence of metastases however Five months later angiography was repeated with the same result The abdomen was reopened and the liver once more palpated but still no metastases were found The ligamentum teres hepatis however now ran through an intrahepatic channel approximately 3 cm wide which penetrated the ventral hepatic surface about 3 cm from the margin i e at the site of the apparent anomaly The case has been followed for three years but no signs of recurrence of the growth or metastases have appeared

Laparotomy in another case revealed that the ligamentum teres hepatis ran intrahepatically through a channel several centimetres in width According to available textbooks the ligamentum teres lies in a groove on the inferior

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Acknowledgements

The author takes this opportunity of thanking Dr Witold Rosowski for his help with the physical examinations and laboratory testing of the factory workers in the control group The author is also most grateful to Mr Tadeusz Ciesla Director of the Marine High School in Wroclaw for his assistance in the organization of the students examinations

SUMMARY

The roentgenologic characteristics of the gastro esophageal vestibule and its measurement in 676 patients with abdominal diseases and in 123 controls are described The length diminishes slightly with age but is not influenced by abdominal conditions

ZUSAMMENFASSUNG

Die rontgenologischen Erscheinungen des gastro oesophagealen Vestibulums und dessen Grosse wurden an 676 Patienten mit Bauchbeschwerden und an 123 Kontrollen studiert Die Lange des Vestibulums nimmt mit zunehmendem Alter leicht ab wird aber nicht von Bauchleiden beeinflusst

RÉSUMÉ

Description des caractéristiques radiologiques du vestibule gastro oesophagien et de ses mesures chez 676 malades atteints d affections abdominals et chez 123 témoins Sa longueur diminue un peu avec l age mais n est pas modifiée par les affections abdominales

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Table

Course of the ligamentum teres hepatis in relation to the liver

	Wholly superficial course	Membrane above the ligament	Intrahepatic ligament course Depth of enclosing channel (cm) <1			1 1—2	2 1—3
			Length of enclosing channel (cm) <3	3—5 9	>6	>6	>6
Males	16	9	8	6	4	3	—
Females	11	14	4	4	3		1
Total	27	23	12	10	7	3	1
Per cent	60 2				34 9	3 6	1 2

the liver The characteristic site of the embedded ligament close to the hilum with the common hepatic artery running and branching off caudal to it, should be kept in mind when assessing roentgenologic anomalies in this region

SUMMARY

The position of the ligamentum teres hepatis was investigated in a consecutive series of 83 autopsies The ligament ran slightly below the surface of the liver in 35 *and more than 1 cm* deep in the hepatic parenchyma in 5 of cases At angiography the intrahepatic course may erratically suggest a poorly vascularized tumour

ZUSAMMENFASSUNG

Die Lage des Ligamentum teres der Leber wurde in einer Folge von 83 Sektionen studiert In 35 der Falle verlief es ein wenig unter der Leberoberflache und in 5 der Falle mehr als 1 cm tief im Parenchym Falls das Band *tief* verlauft kann es bei der Angiographie einen schlecht durchbluteten Tumor vortauschen

RÉSUMÉ

Les auteurs ont étudié sur une série de 83 autopsies consécutives la position du ligament rond du foie Ce ligament était situé un peu au-dessous de la surface dans 35 des cas et plus que 1 cm enfoncé dans le parenchyme hépatique dans 5 % des cas Son trajet intra hépatique peut faire penser sur l angiographie qu il y a une tumeur peu vascularisée

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RAUBER KOPSCH Lehrbuch und Atlas der Anatomie des Menschen Vol II Georg Thieme Leipzig 1951

aspect of the liver, the sulcus venae umbilicus or fissura ligamentum teretis. RAUBER-KOPSCH (1951) stated however that a bridge of liver tissue may be present below the ligament and form a channel for it within the organ.

Since an anomalous course of the ligamentum teres hepatis may influence the course of intrahepatic vessels, we made a study of 83 consecutive autopsy cases (46 males and 37 females), with no evidence of hepatic disease, primarily with a view to investigate whether the ligament lay superficially or was embedded in the liver. Covered ligaments were dissected free, and the length and width of the enclosing channel were measured with a ruler and calipers.



Angiogram showing an avascular zone at the hilus hepatis.

Results and Discussion

As may be seen from the Table, the ligamentum teres hepatis in 60% of our cases ran wholly superficially, or was covered only by a very thin membrane without other tissue. In 35% of the cases the ligament lay in a channel at a depth of less than a centimetre, and in 4% it was contained in a channel more than 6 cm long laying at a depth of between 1 and 2 cm in liver tissue. In one case, finally, the channel lay between 2 and 3 cm below the liver surface and was slightly over 6 cm in length. The common hepatic artery branched off caudal to the ligament in all the cases in which the ligamentum teres hepatis was embedded in the liver.

Angiography and scintillography of the liver are the more important of the currently available methods of diagnosing intrahepatic tumours. The angiographic diagnosis of an avascular tumour is based essentially on the recognition of vascular displacements. The affected vessels are usually arched. An anomalous course of the ligamentum teres hepatis may produce similar appearances.

The investigation disclosed that the ligament not infrequently runs within

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR Á KOVACS), SEMMELWEIS HOSPITAL, BUDAPEST, HUNGARY

ROENTGENOLOGIC STUDY OF THE LARYNGEAL FUNCTION IN SINGERS

by

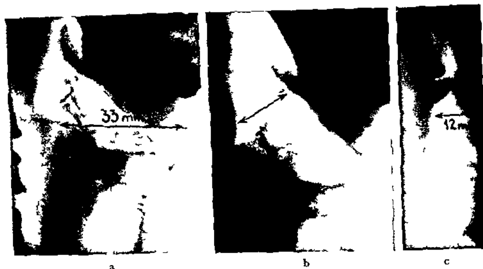
ÁKOS KOVÁCS

The oblique asymmetric roentgenogram (KOVÁCS 1960) will produce a representation of the larynx during singing, and serial roentgenography or cineroentgenography will further assist in the investigation of its function. The morphologic and functional changes present in the larynx of singers, compared to people without any special vocal talent, will now be discussed.

The vertical, horizontal and sagittal diameters of the larynx are 7, 4 and 3 cm in the male and 5, 3.5 and 2.5 cm in the female, respectively; the female larynx is also more rounded. Apart from these sex variations, a considerable difference is apparent between singers and non singers, not only in the capacity of the lungs and the diameter of the thorax, but also in the shape of the larynx and the length of the vocal chords (HUSSON 1962). Soprano singers with a sufficiently loud voice have a larynx that is larger in the sagittal than in the horizontal diameter; furthermore, the trachea is not cylindric in shape but is compressed from side to side (Fig. 1).

A difference is also evident in the length of the vocal chord in individual singers. ZIMMERMANN (1938) obtained the following values at laryngoscopy

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a b c

Fig 1 Soprano singer s larynx s larger ır the sag ttal than ın the hori ontal diameter

bass 24 to 25 mm baritone 21 to 27 mm tenor 18 to 20 mm alto 18 to 19 mm mezzosoprano 18 to 21 mm and soprano 14 to 17 mm

A roentgenologic examination may reveal variations in the thickness of the vocal chords The vocal chord of a singer with a soprano voice is about 2 to 3 mm in diameter while that of a bass singer is thicker than a fingertip (Figs 1 and 5) Moreover a definite difference exists in the shape of the vocal chords between trained singers and those singing only occasionally The vocal chord of a singer while singing in the upper register becomes thinner especially at the edge and often bends upwards taking the shape of the beak of a bird of prey (Fig 1c) The purpose of this bending is to cause the vibrating portion of the vocal chord to narrow According to the elementary law of physics of vibrations when the same amount of energy acts upon two vibrating systems of different mass, the frequency of vibrations will be inversely proportional to the mass Hence for example if a metal plate is gripped in a vice and set in vibration the smaller the part is that protrudes from the vice the higher is the sound produced Again if the edge of the plate is bent like a beak the vibrating area will be reduced and the sound will be higher Similar results may be produced with a slip of paper put in front of the lips and set in vibration by the breathing

Phoneticians have long suggested from laryngoscopic examinations that a mechanism similar to the above must be present in the larynx of a singer For example FORCHHAMMER in his textbook on phonetics published as early as

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Fig 3 The vestibule dilates when a louder tone is formed

muscles and ligaments allow the various parts of the larynx freely to dilate and contract

In a series of roentgenologic examinations four parts of the larynx difficult to reach by other means were studied and compared in trained singers and controls with no vocal talent These were in order of significance true vocal chords false vocal chords piriform fossae and the ventricles of Morgagni This method of testing permits singers with ordinary voices to be distinguished from talented vocalists

There are considerable differences between singers and non singers in the proportions of muscle and ligamentous tissue making up the true vocal folds The musculature of the vocal chord in singers is well developed and powerful and it readily contracts and relaxes In a bass singer the thickness of the vocal fold measured in the frontal plane may be found to increase on phonation up to 3 times its original diameter (Fig 5) In contrast the vocal fold of someone unable to sing is bulky and fixed in diameter, the sound produced is consequently small or has practically no range (Fig 6)

False vocal chords Good singing requires independent accurate and well controlled movements of the true and false vocal chords The participation of the latter in the mechanism of sound production has been clarified mainly by observations in patients who have had operations upon the larynx Following removal of the true chords most of the patients sooner or later begin to speak using the false chords to produce sonant sounds It is also commonly observed



Fig 2 The vocal chord becomes thicker when a 'forte' tone is formed

1928, described four registers of singing (1) full register, the vocal chord vibrates in its full length and width, (2) marginal register, the edge of the vocal chord vibrates, (3) middle register, a transition between the two former registers, (4) short register, the considerably shortened vocal chord vibrates

Laryngeal function

True vocal chord The shape of the true vocal chords alters according to the loudness of the voice By formation of a 'forte' tone, an increased stream of air vibrates a thicker chord, while a 'piano' sound is associated with a thinner and narrower vocal chord This difference is clearly observable in both men and women (Fig 2) Whispering is not accompanied by further narrowing of the chord but, as is known from laryngoscopy, the two chords, of about the same thickness as observed on piano phonation, fail to close (Fig 13, d and e) The louder the tone, the larger the pipe must be Among the 'wind instruments', it is the trumpet that has the loudest voice In analogy, nerve impulses in the human subject cause the vestibulum to dilate and not infrequently to double in volume (Fig 3) The trachea also dilates in young children, the soft, elastic tracheal cartilages become stretched and the subglottic area dilates to produce a loud voice (Fig 4)

The range of voice is a functional ability of the human larynx based on anatomical conditions that can be subjected to functional roentgen examination and recorded The larynx of a trained singer differs from that of a non singer To produce a wide vocal range it is necessary that the elastic cartilages, and the



Fig 5 Larynx of a bass singer a) Expiration b) The vocal fold increased up to 3 times its original diameter on phonation of a high note



Fig 6 Larynx of a non singer There is no difference to be seen in the vocal fold on phonation of high (a) and low (b) sounds

bulge It can however be established whether the false chord is able to flatten during phonation and hereby conclusions as regards the volume of muscle may be drawn It could be shown that in low tone phonation, when the true vocal chord is thick and the larynx is displaced downwards the false chord becomes considerably thinner This phenomenon is accompanied by dilatation of the piriform sinuses The regions of the false chords are stretched partially by the external muscles of the larynx dilating the piriform sinuses from the sides and partially by the m vocalis dilating them from below, so that a more dilated laryngeal tube is formed above the glottis (Fig 7) The opposite may be observed during high tone phonation The thinner m vocalis fails to exert a stretching effect from below while the piriform sinuses become smaller and move upwards with the entire larynx The false chords will thus become thicker bulge and hang down into the larynx above the glottis which thus narrows This change was absent in soprano and mezzosoprano singers (five cases) in whom the false chord was extremely thin and often membraneous (Fig 8) In such singers only a knot like bundle was seen to be formed on the membraneous plate made up of the aryepiglottic fold and the muscles of the false chord Possibly this bundle is actually the muscle bundle of the ventricular fold (Figs 8 and 9)



Fig 1 The trachea dilates when a forte tone is formed

that patients with lesions of the recurrent laryngeal nerve generally learn to use the false chords for phonation Laryngoscopy has shown that the false chords approximate while the arytenoid cartilages intercross, the epiglottis tends to bend downwards and the mucosa of the larynx forms a fold running laterally and backwards This latter is the product of a hypertrophic muscle, the m stylopharyngeus (RETHI 1952) The latter is attached above to the styloid process of the cranium and runs downwards and medially to give a bundle to the epiglottis and form the pharyngeo epiglottic fold, while the remainder continues as the aryepiglottic muscle behind the transverse and oblique adductor muscles, some of the fibres reaching the upper margin of the cricoid cartilage If in paralysis, for example, the transverse and oblique adductor muscles are removed in order to overcome paramedian fixation, a sound may still be produced by sufficient training of the false chords Contraction of the aryepiglottic muscle thus causes the aryepiglottic fold to become shorter, while the epiglottis bends downwards and the false chords approximate and touch This is evidence that movement of the false chords may under certain circumstances take place independently of the arytenoid cartilage On the other hand, the function of the false chords in healthy individuals is to modify the shape of the resonance tube, and serves only in the second place as a sound producing instrument The movement of the stylopharyngeal muscle must thus be coordinated with the m vocalis, this coordinated movement has been carefully studied by the authors

Oblique asymmetric roentgenograms of the vocal chords will not reveal the proportion of muscle, connective tissue, mucosa, and fat present in the



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bulge It can however be established whether the false chord is able to flatten during phonation and hereby conclusions as regards the volume of muscle may be drawn It could be shown that in low tone phonation when the true vocal chord is thick and the larynx is displaced downwards the false chord becomes considerably thinner This phenomenon is accompanied by dilatation of the piriform sinuses The regions of the false chords are stretched partially by the external muscles of the larynx dilating the piriform sinuses from the sides and partially by the m vocalis dilating them from below so that a more dilated laryngeal tube is formed above the glottis (Fig 7) The opposite may be observed during high tone phonation The thinner m vocalis fails to exert a stretching effect from below while the piriform sinuses become smaller and move upwards with the entire larynx The false chords will thus become thicker bulge and hang down into the larynx above the glottis which thus narrows This change was absent in soprano and mezzosoprano singers (five cases) in whom the false chord was extremely thin and often membraneous (Fig 8) In such singers only a knot like bundle was seen to be formed on the membraneous plate made up of the aryepiglottic fold and the muscles of the false chord Possibly this bundle is actually the muscle bundle of the ventricular fold (Figs 8 and 9)



Fig. 4. The trachea dilates when a forte tone is formed

that patients with lesions of the recurrent laryngeal nerve generally learn to use the false chords for phonation. Laryngoscopy has shown that the false chords approximate while the arytenoid cartilages intercross, the epiglottis tends to bend downwards and the mucosa of the larynx forms a fold running laterally and backwards. This latter is the product of a hypertrophic muscle, the m. stylopharyngeus (RÉTHI 1952). The latter is attached above to the styloid process of the cranium and runs downwards and medially to give a bundle to the epiglottis and form the pharyngeo-epiglottic fold, while the remainder continues as the aryepiglottic muscle behind the transverse and oblique adductor muscles, some of the fibres reaching the upper margin of the cricoid cartilage. If in paralysis, for example, the transverse and oblique adductor muscles are removed in order to overcome paramedian fixation, a sound may still be produced by sufficient training of the false chords. Contraction of the aryepiglottic muscle thus causes the aryepiglottic fold to become shorter, while the epiglottis bends downwards and the false chords approximate and touch. This is evidence that movement of the false chords may under certain circumstances take place independently of the arytenoid cartilage. On the other hand, the function of the false chords in healthy individuals is to modify the shape of the resonance tube, and serves only in the second place as a sound producing instrument. The movement of the stylopharyngeal muscle must thus be coordinated with the m. vocalis: this coordinated movement has been carefully studied by the authors.

Oblique asymmetric roentgenograms of the vocal chords will not reveal the proportion of muscle, connective tissue, mucosa, and fat present in the



Fig. 8a Fig. 8b Fig. 9

Fig. 8. Larynx of a soprano singer. The false chord is extremely thin and membraneous.

Fig. 9. Larynx of a soprano singer. A "knot" is formed on the membraneous false chord.

chords are not necessary under normal conditions for the production of sound. This assumption has been based on the constant post mortem finding of the absence of false chords in subjects who had been known to speak normally during life.

The role played by the false chords in phonation under normal circumstances is more or less a negative one according to PRESSMAN & KELEMEN. They appear in many singers to flatten against the lateral wall of the larynx, thus diminishing their shelf like character; this opens the larynx above more widely, and allows an uninterrupted passage of the sound waves that have formed at the level of the true vocal chords. In others, this action is reversed during phonation and the false chords tend to approximate towards the midline. The resultant tone is comparatively unpleasant due to a muffling of the sounds produced and interference with the smooth passage of sound waves from the larynx to the upper resonating chambers. The approximation also tends to reflect the waves back into the larynx.

PANCONCELLI CALZIA (1953) suggested that the false chords play only a passive part in the mechanism of phonation. The present observations are inconsistent with this view, since it was found that both the shape and mass of the false chords, as well as the extension of the supraglottic area, greatly vary while singing or speaking in a clear colourful voice. In the theatre, as well as in everyday life, whenever the sound is forced or violent, the true vocal chords retract and the false chords move forwards.

The vocal chords in a series of investigations were observed during the

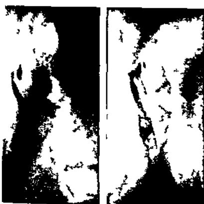


Fig 7 A p and lateral roentgenograms of the larynx of a mezzosoprano singer On deep tone phonation a dilated laryngeal tube is formed (b) and the vocal chords are shortened (e) High tones are formed in (a) and (b) and an explosive tone in (c)

The mechanism of sound production is not the same in bass and barytone singers The narrowing of the true vocal chords on high tone phonation remains, but the false chords behave differently It seems that the latter contribute to a certain extent to the formation of deep tones in such singers, for it becomes thick and assumes a shape similar to that of the vocal chords (Fig 10) Similar observations were made in singers with an alto voice, the false chord then also resembled a *fold* rather than a bulge The false chord is normally driven by the arytenoid cartilage, but muscles not connected with the arytenoid cartilage are responsible for its fine control in singers If the false chord is stiff, robust, or weak, it fails to form a plica, and the ventricle of Morgagni remains narrow This results in a limited register and a toneless, harsh voice (Fig 6)

In laryngitis, the swelling of the false chord is often more marked than that of the true chord, *which leads to inability to speak or results in a weak* and throaty voice (Fig 11) In spastic dysphonia, the false chord bulges into the lumen of the larynx, causing it to narrow and resulting in a colourless or sometimes harsh, voice (Fig 12 a) When the spasm of the laryngeal muscles relaxes, the true chords again take over the formation of sounds In the case observed by us, normal phonation was restored without surgery after two months' intensive therapy (RETHI 1965) (Fig 12 b)

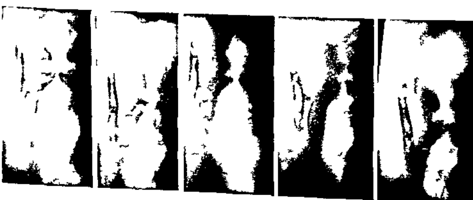
This more detailed study of the function of the false chords appeared to be useful, since a considerable number of writers uphold the view that the false

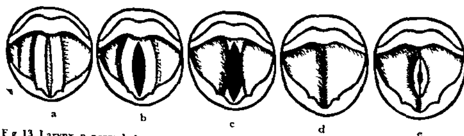


F g 11 Case of la yngit s a) The swelling of the false chord s more marked than that of the true chord b) After heal ng



F g 12 Case of spastic dysphon a a) The false chord bulges into the lumen of the larynx b) After two m nths normal phonation





F g 13 Larynx n normal phonati n (a) soft whisper (b) loud whisper (c) exaggerated sound (d) and g ntly purr ng sound (e)



Fig. 10. Larynx of a baryton singer. a) On formation of tone H_1 the false chord becomes thick and assumes a shape similar to that of the vocal chord. b) Formation of a high tone

formation of a voiced, indifferent sound of medium intensity, and compared with an 'A' tone, first softly, then loudly whispered. The glottis was wide in both instances, which is a natural consequence of whispering, but on a loud whisper the ventricles of Morgagni contracted, the false chords being pushed forwards and the contour of the true chords becoming edged. Thus, in the latter case the false chords while being pushed forwards restrict the volume of the vestibule to a maximum, although only immediately above the true chords. The false chords nearly touch while the interspace between the true chords becomes wider. If a softly purring sound is formed, the true chords approximate, while the false chords bulge outwards, the vestibule in such cases is rather narrow (Fig. 13).

Piriform sinuses. A part of the supraglottic resonant space is formed by the two piriform fossae or sinuses, which anatomists describe as a hollowing out at the sides of the thyroid cartilage, lined with mucous membrane and forming two pendant saccules. One might say that the sinuses surround the aperture of the larynx (Fig. 14). Their function has been studied by BOURDON et coll. (1963), and others. The fossae filled with contrast medium, are depicted either by cineroentgenography or serial roentgenography while the patient is instructed to breathe and inflate the larynx and Valsalva's manoeuvre is performed. It has been demonstrated that the sinuses in healthy subjects undergo considerable changes in shape while being subjected to these manoeuvres, whereas in case of tumour infiltration filling is deficient.



Fig 15 In a coloratura singer the saccule expands during deep-tone phonation (a) and the ventricular fold b comes thick on phonation of a high note (b)

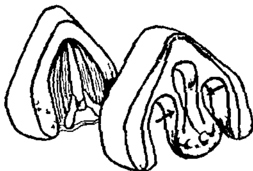


Fig 16 Horizontal section of the larynx showing vocal fold (left) and ventricular fold (right) The saccule is dilated the ventricular fold is thickened and the vestibule is narrow

be emphasized that the vocal chord at the same time alters in the opposite way

The present results give some information on the complicated mechanism that controls sound formation Thus phonation is closely linked with the function of not only the vocal chord but also with that of the piriform sinuses and the aryepiglottic and ventricular folds Besides the movements of the true and false chords which are controlled by the arytenoid cartilage the piriform sinuses and especially their medial walls, as well as the part of the false chord that lies below the aryepiglottic folds perform separate movements that can influence the shape of the resonating tube All these factors not only alter the shape of the lower part of the tube but play an essential role in generating and damping vibrations These parts of the larynx seem to be the most important after the vocal chords in the production of a fine singing voice

Roentgenograms of 25 healthy subjects revealed that well developed sinuses extend quite deeply Most of these subjects possessed the ability of producing high and deep tones relatively easily In those in whom the piriform sinuses could not be demonstrated there was usually inability to produce high tones

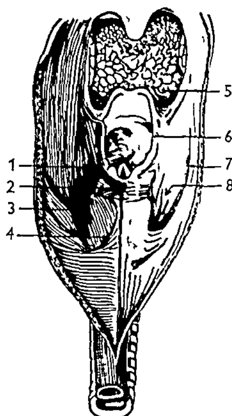


Fig 14 Longitudinal section showing pharynx and larynx with saccule
1 — m aryepiglotticus
2 — m interarytaenoideus
3 — lamina thyroidea
4 — m cricoarytaenoideus posterior
5 — vallecula epiglottica
6 — *plica aryepiglottica*
7 — lamina thyroidea margo posterior
8 — recessus piriformis

Deep piriform sinuses are commonly observed in subjects with a clear singing voice Their roles in deep and high tone phonation have already been discussed in connection with the vocal chords The sinus dilates on phonation, the rate of dilatation depending on the loudness of the voice produced Its medial wall, the plica aryepiglottica, dilates and bulges inward only during *high tone phonation The piriform sinus is 'hollowed out' in deep tone phonation*, its outer contour being often broken above the upper margin of the thyroid cartilage The ventricular fold is small and its upper part, which continues in the aryepiglottic fold, is stretched to form a membrane (Fig 15) The sinus in high tone phonation *is raised more than the larynx, so that it emerges* from between the thyroid cartilages Its medial wall, the false chord forms a thick bundle which presses into the vestibule and thus narrows the lumen (Fig 16) The shape of the ventricle of Morgagni is altered only secondarily as a result of these changes If the false chord is thick the ventricle becomes deeper, while a thin pellicular chord produces a smaller ventricle It should

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RADIOLOGIC ESTIMATION OF KIDNEY WEIGHT

by

HANS LUDIN

The size of kidneys may be judged radiologically from their length (KARN 1962 and others) or area (MOELL 1956 LUDIN 1961) determined either in conventional films urograms angiograms or tomograms (LUDIN 1961) Since the kidneys may be long and slender or short and broad it seems appropriate to take both their length and width into account This does however involve some calculation the result the kidney area is a somewhat imaginary magnitude to be correlated only with its normal values These have not been systematically determined in children and correlate poorly with body surface (MOELL 1961) In order to eliminate calculation and to find a standard firmly based on reproducible measurements some regressions were calculated between the length and area and the weight of the kidney and a set of nomograms was computed allowing the weight of the kidney to be estimated from its length and width

Material and Methods Our records enabled us to trace 428 cases in which autopsy had been performed between 1959 and 1964 and in which a suitable roentgen examination of the abdomen or the kidneys proper had been carried out In 16 of these 428 cases kidney weight was not evident from the autopsy

Submitted for publication 16 August 1965

SUMMARY

The differences in the roentgenologic shape of the larynx between singers and non singers are described The anatomy is discussed and the role of the various parts of the larynx in producing different sounds is considered

ZUSAMMENFASSUNG

Die Kehlkopfe von Singern und Nichtsingern wurden radiologisch verglichen Die anatomischen Grundlagen werden besprochen und die Bedeutung der einzelnen Kehlkopfabschnitte fur die Stimmbildung wird erortert

RÉSUMÉ

Description des différences de forme radiologique du larynx des chanteurs et des non chanteurs L auteur étudie l anatomie et le role des différentes parties du larynx dans la production des différents sons

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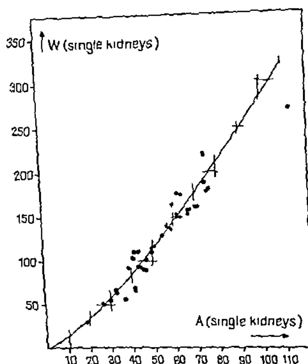


Fig 2 Regression of we gl t W on area A of s ngle kidneys in g oup 4 computed f om formulas (1) and (3) respectively

was available from the autopsy records whereas kidney weight had bee recorded separately for each kidney in 3 cases and in 6 cases for one kidn only

The length L and area A of the kidneys were measured on the films tomograms both the values of L and the width T were reduced by a factor 0 97 independent of the tomographic layer suitable for measurement (LEDIN 1961) Kidney weight W as well as L and A (calculated from L and were tabulated dividing the material into the following groups

Group 1 Compounded values of W A and L of both kidneys of cases exa ined one month or less before death (54 cases)

Group 2 Compounded values of W A and L of both kidneys of cases examı one to fourteen on the average about five months before death (32 cases)

Group 3 Compounded values of W A and L of both kidneys of cases cluded in groups 1 and 2 (86 cases) One case its kidney weight being grams was excluded from group 3 but not from group 4

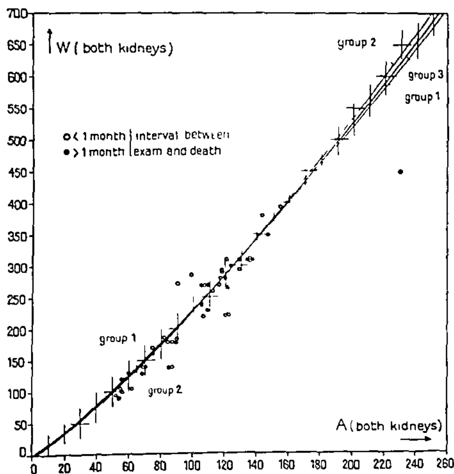


Fig. 1. Regression of the compounded weight W in g on area A in cm² of both kidneys in groups 1, 2 and 3, computed from formulas (1) and (3) respectively.

records, 165 of the remaining 412 cases were excluded from the series because of the presence of e.g. hydronephrosis, cysts, and tumours. Of the remaining 247 cases, 153 were unsuitable for kidney measurements for technical reasons, such as inadequate film quality or meteorism for instance, most often in survey films of the abdomen.

The kidneys could be measured on the films in 94 cases, namely on 18 conventional films, 27 urograms and 49 tomograms. The average age of the males was 57.8 years, of the females 58.7 years. There were no children except a 6 year old boy. In 9 patients findings at autopsy were normal, the most common changes were oedema, chronic interstitial nephritis and renal hyperplasia. The series includes one case with intoxication by an unknown substance and a combined kidney weight of 720 grams.

Unfortunately, in 85 of the 94 cases only the weight of both kidneys together

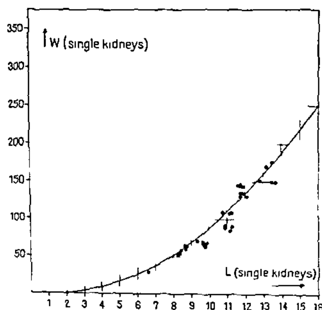


Fig 4 Regression of weight W on length L of single kidneys in group 5 computed from formulas (2) and (4) respectively

Of the functions

$$W = a \cdot A^{b} \qquad (1)$$

and

$$W = c \cdot L^{d} \qquad (2)$$

the parameters a, b, c and d were computed. The non linear regressions shown in Figs 1 to 4 were computed from

$$\log_{10} W = \log_{10} a + b \cdot \log_{10} A \qquad (3)$$

and

$$\log_{10} W = \log_{10} c + d \cdot \log_{10} L \qquad (4)$$

The regression and correlation coefficients were calculated and tested according to FISHER (1958).

Finally, from the resulting regression in group 4, showing the smallest variance (Table 1) about the regression line, two nomograms were calculated, namely

$$L = \frac{(1.60130667 \cdot W)^{0.75\,899}}{0.785398163 \cdot T} \qquad (5)$$

and

$$L_T = \frac{(1.60130667 \cdot W)^{0.752899}}{0.73898286 \cdot T_T} \qquad (6)$$

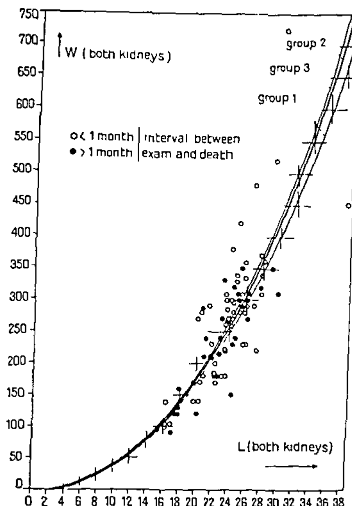


Fig 3 Regression of the compounded weight W in g on length L in cm of both kidneys in groups 1 2 and 3 computed from formulas (2) and (4) respectively

Group 4 Values of W and A of individual kidneys Included were cases in which individual kidney weights were available or in which the weight of one kidney only was found in the autopsy records, as well as all cases of group 3 in which the values of A did not differ more than 10 per cent between the left and right side In these cases, the combined weight of both kidneys was divided into two parts proportional to the individual radiographic kidney areas A For each case, the values A and W of only one of the two kidneys were tabulated, alternating the values of the smaller and the larger kidney (48 kidneys) The error introduced by this method of sampling is in all probability quite small It does not invalidate a comparison of correlation coefficients between groups 4 and 5

Group 5 Values of W and L of individual kidneys The method of selection of cases was the same as in group 4 except for the limitation that cases with asymmetry of L exceeding 10 per cent were excluded (70 kidneys)

Table 3

Divergence between kidney weight values estimated from kidney area values obtained both geometrically from L and T (W_g) and planimetrically (W_p) in each of 139 right and 147 left kidneys in a non selected angiographic material of 171 cases from which all cases of marked hydronephrosis and mass lesions had been excluded The average ratio L/T ranged between 2 02 and 2 12 in the angiographic and autopsy materials differences were statistically insignificant T_p was determined from the planimetric area by the formula $T_p = 4A/\pi L$ W_g and W_p were estimated from L and T_g or T_p by use of the nomogram of Fig 5 The table shows the absolute and relative frequencies of a slight (cf Fig 9 a b d l) moderate (cf Fig 9 g h k m) or marked (cf Fig 9 c e f i) discrepancy between W_g and W_p. In the right and the left kidneys the average value of (W_g/W_p—1) 100 was about + ? per cent

		Right kidneys		Left kidneys	
		Number of cases	Per cent	Number of cases	Per cent
$(W_g/W_p - 1)$ 100	< 5 per cent	82	*59*	95	*65*
	Between 5 and 9 9 per cent	44	*32*	33	*2?*
	> 9 9 per cent	13	*9*	19	*13*
	Total	139	*100*	147	*100*

In adults the standard deviation amounts to approximately 20 per cent (MOELL) The findings of ROESSLE & ROULET seem to indicate that a similar standard deviation would be correct in new borns and infants

Unfortunately it appears that no systematic study is as yet available correlating normal kidney weight with body surface in children and adults The value of 169 4 ± 13 g per m (males) viz 171 6 ± 15 7 g per m² (females) given by MOELL applies to adults only Such an investigation might be easy to carry out on a suitable autopsy material it would be most useful since as is shown below the results of kidney weight estimation from roentgenograms appear to be quite precise

Results

The regression equations for the various groups as well as the respective correlation coefficients are shown in Table 1 The values do not differ significantly between groups 1 2 and 3

The regressions are shown in the following figures

Fig 1 the regression of W on A in groups 1 2 and 3 these three regressions do not differ significantly from the ones presented by LUDIN (1961) and MOELL (1961)

Fig 2 the regression of W on A in group 4 it does not differ significantly from the logarithmic equation of MOELL

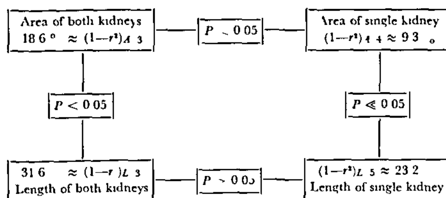
Table 1

Equations and correlation coefficients of regressions (W A) and (W L) shown in Figs 1 to 4

Group	Regression shown in	Equation (1) or (2)	Correlation coefficient r	Number of cases
1	Fig 1	$W = 1\ 036?0\ A^{1\ 17??}$	0 870409	54
2	Fig 1	$W = 0\ 79984\ A^{1\ ?\ 77}$	0 928694	32
3	Fig 1	$W = 0\ 90344\ A^{1\ 1951}$	0 902145	86
4	Fig 2	$W = 0\ 62449\ A^{1\ 3?8}$	0 9?2170	48
1	Fig 3	$W = 0\ 25110\ L^{2\ 1911}$	0 813428	54
2	Fig 3	$W = 0\ 27091\ L^{2\ 1457}$	0 853559	32
3	Fig 3	$W = 0\ 24249\ L^{?\ 1944}$	0 826967	86
5	Fig 4	$W = 0\ 40?01\ L^{\ 3\ 77}$	0 876984	70

Table 2

Comparison of correlation coefficients of regressions (W A) in groups 3 and 4 and regressions (W L) in groups 3 and 5 using the z distribution $(1-r)$ is the fraction of the total variance independent of A and L respectively



L_T and T_T being the linear kidney dimensions as measured on tomograms, the linear reduction factor relative to geometric magnification in conventional films and tomograms amounting to 0 97

Normal kidney weight is much better known in adults than in children The curves of Fig 7, a and b, showing approximate normal kidney weights for males and females in different age groups and per cent deviations from those weights, are based on values roughly averaging the weight values published by ROESSLE & ROULET (1932) and curves obtained from the diagrams of KARN (1962) estimating W from L according to Fig 4 In the adult range the curves agree closely with the findings of THOMA (1882) WALD (1937) and MOELL (1961)

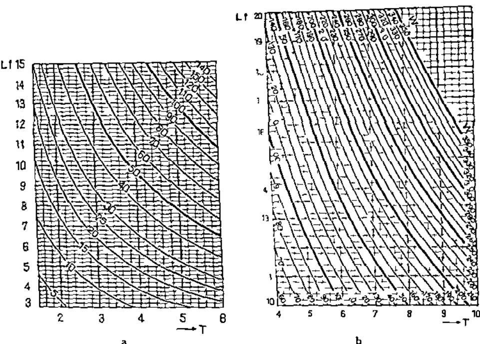


Fig 6 Nomograms for estimating the weight of single kidneys (cu ves) from their length L and width T as me su ed in tomograms computed from formula (6) for small kidneys (shrunken kidneys and children (a) and for normal sized and l rge k dneys (b)

ad III A *significant difference of r between groups* 3 *and* 5 *was probably* absent because of the greater variance about the regression lines (W L) as compared with (W A)

ad IV For this reason the nomograms (Figs 5 and 6) were computed from the regression in group 4 according to the formulas (5) and (6) A comparison of the standard deviation from this regression line 8 3 per cent of $\overline{W}$ and the standard deviation of the weight of normal kidneys about 20 per cent of $\overline{W}$ (see above and Fig 7) suggests the need for a more exact determination of the weight of normal kindeys and a correlation with some measurable body properties

Discussion

The regression and correlation coefficients of the regressions (W A) and (W L) do not differ significantly between groups 1 2 and 3 In fact this difference is surprisingly small On the average the renal enlargement due

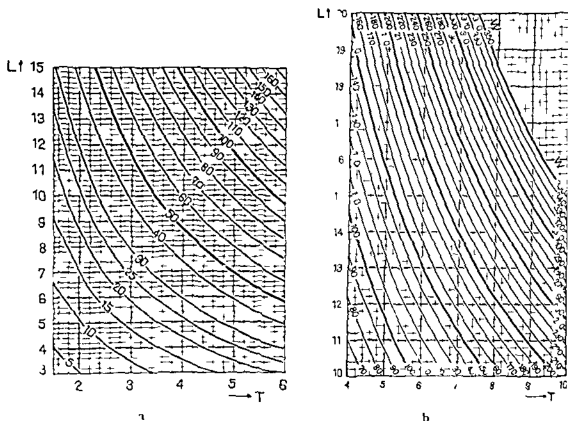


Fig. 5. Nomograms for estimating the weight of single kidneys (curves) from their length L and width T as measured in survey films, urograms or angiograms, computed from formula (5) for small kidneys (shrunken kidneys and children) (a) and for normal sized and large kidneys (b)

Fig. 3 the regression of W on L in groups 1, 2 and 3

Fig. 4 the regression of W on L in group 5

It is evident from Table 2 that

I. W and A are more closely correlated than W and L

II. The correlation of W on A is closer when L and T of each kidney are used separately for the estimation of W

III. *The same does not hold true to a significant degree in the estimation of* W from L

IV. Thus the best correlation is found between A and W of single kidneys

ad I. This result is to be expected from elementary geometrical considerations

ad II. A considerable error is introduced by compounding the values A of each kidney because

$$(a + b)^n \neq a^n + b^n$$

when $n \neq 1$ and $a \neq b$

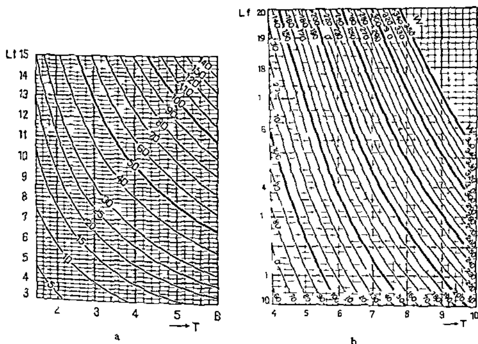


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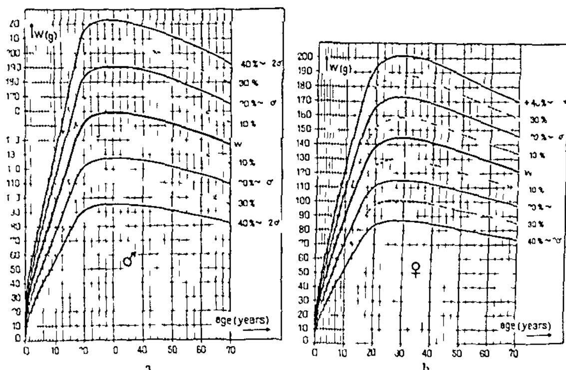


Fig. 7. Normal weight of single kidneys and percentage deviation W_g as a function of age in years in males (a) and in females (b)

to e.g. terminal oedema seen in many cases, seems to influence the kidney weight found at autopsy to a slightly higher degree than does the slow process of kidney shrinking in chronic diseases of the parenchyma. This suggests that, in agreement with MOELL (1961), the average kidney weight remains practically unchanged between roentgen examination and autopsy.

When the retroperitoneal fatty tissue is oedematous or infiltrated it will absorb the roentgen rays approximately to the same degree as does the renal tissue. In such cases the kidneys will therefore be delineated inadequately in conventional films (MOELL 1961) or tomograms (LUDIN 1961). This difference in absorption can be increased by a sufficiently strong nephrographic effect produced by urography or, when the renal excretory function is severely impaired, by selective renal angiography or aortography under Valsalva conditions (LUDIN 1962, 1966). When the retroperitoneal fatty tissue is normally *translucent* and *not* too scanty, the renal outline can be demonstrated much more clearly by tomography than in ordinary films or urograms (LUDIN 1961), even when the kidneys are masked by intestinal contents. Tomography thus obviates emptying of the intestines and this is of special value in the examination of patients suffering from severe renal disease.

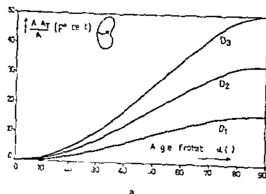
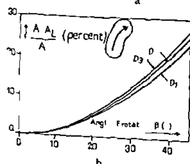


Fig 8 a) Apparent reduction in kidney area caused by rotation of kidney around its longitudinal axis A kidney area when the plane (L T) is frontal A_T when the kidney is rotated Relative kidney dimensions in this example $T = 0\ 500$ L thickness of kidney $D = 0\ 416$ L $D = 0\ 333$ L $D = 0\ 250$ L The curves were computed from the formula (LUDIN 1961)

$$\frac{A - A_T}{A} = 1 - \frac{(1 - a\ a\ )^{1/2}}{(1 - a\ )^{3/2}}\quad a = \frac{4\ d\ o}{T}$$

$$a = \frac{T - D}{4\ d_o - D}\ \sin\ \alpha$$

d being the distance between film and centre of object



b) Apparent reduction in kidney area caused by rotation of kidney around its transverse axis A kidney area when the plane (L T) is frontal A_L when the kidney is rotated Relative kidney dimensions in this example as in (a) The curves were computed from the formula (LUDIN 1961)

$$\frac{A - A_L}{A} = 1 - \frac{(1 - b\ b\ )^{1/}}{(1 - b\ )^{3/2}}\quad b = \frac{4\ d}{L}$$

$$b = \frac{L - D}{4\ d - D}\ \sin\ \beta$$

An important cause of the variance about the regression lines presented is the often considerable rotation of the kidneys around their longitudinal and transverse axes the degree of rotation cannot be judged exactly from films Especially when the kidneys are relatively flat an apparent reduction of the renal area by 10 to 20 per cent may be recorded (Fig 8 a and b cf MOELL 1961)

Estimation of W from L and T evidently depends on an exact geometric definition of L and T No real difficulty exists in measuring L except in the few cases in which it remains uncertain whether or not the left adrenal is included in the renal outline the error thus introduced is however quite small The determination of T is more problematic owing to the variations in shape and longitudinal axis rotation of the kidneys In most cases the medial aspect of their roentgenographic outlines is clearly seen in conventional films and urograms When however at the level of the hilum the medial contour is concave inwards the length of T is a matter of definition In the material presented the medial limit of T has been located at the intersection point of a line perpendicular to the longitudinal axis drawn at the hilar level and a straight line connecting the medial bulges of the upper and lower poles (Fig 9 a and b)

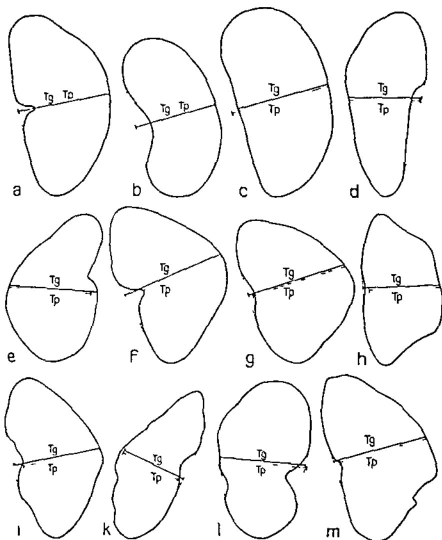


Fig 9

a) Ideal asymmetric ellipse with small funnel shaped hilar concavity $(H_g/H_p - 1)\ 100 = d_{g\ p} = 0$ (per cent) T_g and T_p as in Table 3
b) As in (a) $d_{g\ p} = 0$
c) Square kidney $T_g \ll T_p$ $d_{g\ p} = -10\ 6$ planimetry preferable
d) Tapering kidney $d_{g\ p} = +4\ 2$ illustrates necessity of T_g being an average between larger upper and smaller lower portion of kidney
e) Tapering and bulging kidney $T_g \gg T_p$ $d_{g\ p} = +10\ 2$ planimetry preferable
f) Bulging kidney $T_g \gg T_p$ $d_{g\ p} = +15\ 9$ planimetry preferable
g) Bulging kidney $d_{g\ p} = +5\ 0$ bulging has been partly compensated in determining T_g
h) Broadly bulging kidney $d_{g\ p} = +5\ 1$ compensation of convexities by concavities
i) Lemon shaped kidney $T_g \gg T_p$ $d_{g\ p} = +1[illegible]\ 2$ planimetry preferable
k) Indented kidney $T_g \sim T_p$ $d_{g\ p} = +9\ 9$ irregular outline and some tapering partly compensated planimetry preferable
l) Indented and tapering kidney $d_{g\ p} = +2\ 5$ adequate compensation
m) Locally indented kidney $T_g \sim T_p$ $d_{g\ p} = +5\ 3$ partial compensation

This practice therefore has to be adhered to when using the nomograms of Figs 5 and 6

This difference in determining the length of T contributes again, to the variance about the regression lines (H, A) It is encountered especially in evaluating angiograms and certain tomographic exposures in which the renal outline is more clearly demonstrated than in ordinary films and urograms The results of a comparison of the values of T determined both planimetrically and geometrically in a series of 171 angiograms shown in Table 3 agree with the statement of MOELL (1956) that the average area values obtained by these two methods are nearly identical Not infrequently however, there are cases in which the shape of the kidneys deviates markedly from normal (Fig 9) The determination of T is then especially delicate for the following reasons

In most cases the renal outline approximates quite closely to an asymmetric ellipse The area values of symmetrical and asymmetrical ellipses are equal i e defined by L and T Very irregularly shaped kidney contours may however, deviate considerably from the ideal asymmetric ellipse

The real aim of radiologic kidney size determinations is an estimation of the volume (= 0 983 cm³/g MOELL 1961) or weight of the renal parenchyma proper This is only possible when the ratio between parenchyma and other structures such as the pelvicalyceal system and the peripelvicalyceal fatty tissue does not deviate appreciably from normal Cases of marked hydronephrosis cysts and tumours are therefore not suitable for this method

Acknowledgements

The author takes this opportunity of expressing his gratitude to Prof A A Wertheman Director of the Institute of Pathology and F Seiler physicist at the Institute of Applied Physics Basle University for their help as well as to Miss R Alpstag Mrs E Faust Miss H Harder Miss V Kaufmann Mrs H Schwenk and Miss L Senn for their assistance

SUMMARY

A comparison of the variance of regressions between radiographic kidney length or area and autopsy weight in 94 cases shows that the area and weight of single kidneys are most closely correlated the fraction of the variance about the regression line independent of the area values $1-r^2$ being less than ten per cent The reasons for the variance especially physiologic kidney rotation and problems presenting in measuring kidney width are discussed

ZUSAMMENFASSUNG

Ein Vergleich der Streuung der Regression zwischen rontgenologisch bestimmten Werten der Nierenlangen bzw Nierenflachen einerseits und dem autoptisch gefundenen Nierengewicht andrerseits zeigt bei 94 Patienten dass die Beziehung zwichen den Nierenflachen und Gewichtswerten von Einzelnieren am engsten ist indem die Unbestimmtheit $1-r^2$ weniger als 10 betragt Die Grunde fur die Streuung werden diskutiert besonders die physiologische Nierenrotation und die Schwierigkeiten bei der Messung der Nierenbreite

RÉSUMÉ

La comparaison de la variance des régressions entre la longueur radiographique du rein ou sa surface et son poids à l autopsie dans 94 cas montre que la surface et le poids d un rein sont en étroite corrélation la fraction de la variance autour de la ligne de régression indépendante des valeurs de la surface *1—r étant inférieure à dix pour cent* L auteur examine les raisons de la variance en particulier la rotation physiologique du rein et les problèmes que pose la mesure du rein

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FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY (DIRECTOR PROF F KNUTSSON) AND THE DEPARTMENT OF ORTHOPEDIC SURGERY (DIRECTOR PROF T HIERTONN) THE UNIVERSITY HOSPITAL UPSALA, SWEDEN

RADIOGRAPHIC DETERMINATION OF THE BONE MINERAL CONTENT IN AMPUTATION STUMPS

by

LARS BJORK and RUDOLF LEMPERG

Increasing attention is paid nowadays to the rehabilitation of patients with leg amputations One problem is the considerable demineralisation of the bones that sometimes occurs in amputation stumps A simple and reliable technique for its mensuration would therefore be useful Various methods have been used to determine the bone mineral content in patients BJORK (1965) found a modification of the method of KEANE SPIEGLER & DAVIS (1959) useful in osteoporosis and the present authors have modified this method further to make it suitable for the determination of the bone mineral content of the tibia

Technique The principle of the previously described method to determine the bone mineral content of the ulna (BJORK 1965) has been used The modification consists mainly in giving a different size to the water tank it measures 15 cm × 15 cm × 15 cm and is boot shaped to accommodate the lower leg and the foot of the patient

The aluminium step-wedge is placed as close as possible to the upper part

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Tibia and fibula (p.a.) and aluminium step wedge in the water tank. The density of the tibia in the midline is compared with the density of the wedge; the water compensates for differences in soft tissue thickness but the thickness of the subcutaneous fat should be noted.

of the tibia. A frontal roentgenogram of the tank with the tibia and the step wedge is obtained (see the accompanying illustration). The film focus distance is 130 cm and the object film distance as great as 20 cm to reduce the scattered radiation. The exposure factors have been 60 kV and 250 mAs. Thereafter, a lateral view of the tibia is obtained outside the water tank and from this the thickness of the bone is measured.

The density at points along the midline of the tibia is measured and, with the density of the steps of the wedge as a reference, the bone mineral content of the tibia is calculated. The measurements have been made at 9, 9.5, 10, 10.5 and 11 cm from the proximal end of the tibia. The values obtained were very similar and variations above 5 per cent were encountered.

The mean values of five determinations in eight patients with amputations of one of the lower legs are given in the Table. The intact leg was used as a control and the quotient between the mineral content of the amputated and the normal leg was calculated. As in the ulna (MAYO 1961, BJORK 1965) the individual variations in mineral content of the tibia were considerable. In all patients, the mineral content of the amputated tibia was lower than that of the control leg but there were considerable variations in the quotient

Table

Age in years	Cause of amputation	Muscular function	Maximal walking distance	Bone mineral content in tibia mg/cm		Quotient amputated versus normal leg
				Amputated leg	Normal leg	
69	Chronic infection	Good	200 m	t0	180	0 33
5?	Congen malformation	Poor	100 m	36	8?	0 42
6?	Trauma	Fair	1 000 m	30	6	0 49
33	Trauma	Excellent	Unlimited	104	187	0 57
49	Trauma	Excellent	Unlimited	58	94	0 62
46	Trauma	Fair	Unlimited	220	300	0 72
3?	Trauma	Poor	Unlimited	200	265	0 76
50	Trauma	Good	Unlimited	9?	11?	0 82

between the two In this small group of patients the highest mineral content of the amputated tibia was found in those who had a normal or near normal ability to walk with the aid of a prothesis On the other hand muscular function seemed not to be correlated to the mineral content of the amputated leg These findings have to be confirmed on a larger material but they may support the theory that not only muscular activity but also the load of body weight are essential for adequate mineralisation of the bones of the legs As expected there was generally a decrease in the bone mineral content with increasing age both of the amputated and the control tibia

The often thick subcutaneous fat is an important source of error in these studies (see the figure) Fat has a density lower than water and may give artificially low values of the mineral content However absolute values of the mineral content of the tibia are relatively unimportant when the control leg can be used as a reference Only when there are differences between the amputated and the control leg in the thickness of the subcutaneous fat has this source of error to be considered

SUMMARY

A special method of determining the bone mineral content of the tibia is described In eight patients with amputation below the knee the mineral content of the amputated tibia was lower than that of the control leg

ZUSAMMENFASSUNG

Eine Spezialmethode fur die Bestimmung des Mineralgehaltes der *Tibia* wird angegeben Acht Patienten mit Amputation unterhalb des Knies zeigten geringeren Mineralgehalt in der amputierten Tibia als in der Vergleichsseite auf

RÉSUMÉ

Description d une méthode spéciale de détermination de la teneur minérale osseuse du tibia Chez huit malades amputés au dessous du genou la teneur minérale du tibia amputé était inférieure à celle de l autre tibia

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^{131}I INULIN FOR QUANTITATIVE DETERMINATION OF GLOMERULAR FILTRATION RATE

Comparative study of chemical and nuclear clearance in man

by

G HOR H STEINHOFF H G HEINZE H W PABST and D HADID

Inulin clearance is usually employed to determine renal glomerular function due to the widely acknowledged conception that inulin is filtered out from the glomeruli in the same concentration as in the plasma (ref 1 8 11 13 17 18 22 28 30 31 37—39 45—47 55) Among the prerequisites of an ideal clearance substance BERLYNE et coll (1964) stated that it must not be protein bound in the plasma must not be secreted nor reabsorbed by the tubules nor should it be difficult to estimate chemically In contrast to previous reports ref 15 23 36 44 54) recent investigations of microinfusion of the nephron again confirmed that there is no transtubular absorption nor secretion of inulin ref 2 22) as it is known to occur with creatinine (ref 3, 21 30 40 41) Furthermore the clearance of inulin is independent of urine flow (WRIGHT 1932 and of the inulin content in the lymph (PAPP 1964) Chemical determinations of inulin usually applied for clinical clearance techniques are however time consuming and sometimes inaccurate (ref 7 8 12 13 29 31 39 48) so that they have gained only limited acceptance

Submitted for publication 7 July 1966

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Table 1

Patient	Urine flow (ml/min)				Clearance (ml/min/1.73 m²)			
	1	2	3	Average	^{131}I inulin A	Inulin B	Difference (ml/min) A—B	Quotient ^{131}I inulin/inulin A/B
	(Clearance periods)							
1	0.85	0.89	0.81	0.85	65.2	65.0	+ 0.2	1.003
2	1.20	2.26	3.49	2.36	54.0	63.3	— 9.3	0.85
3	7.70	2.25	6.55	5.50	103.0	109.8	— 6.8	0.94
4	0.2	0.33	0.40	0.33	109.0	121.3	— 12.3	0.90
5	5.03	6.05	7.31	6.13	118.7	116.5	+ 2.2	1.02
6	1.56	3.90	3.61	3.02	98.0	97.8	+ 0.2	1.002
7	6.94	8.76	9.20	8.30	63.5	80.8	— 17.3	0.79
8	0.93	6.62	4.82	4.12	111.6	109.8	+ 1.8	1.02
9	0.53	0.72	—	0.63	77.7	85.5	— 7.8	0.91
10	9.82	15.40	—	12.61	132.8	143.0	— 10.2	0.93
						Average	— 5.90	0.94

because of the physical qualities of ^{14}C cannot be excluded. The gamma-emitting isotopes are therefore of special interest for practical use. Clearance measurements with ^{131}I inulin in dogs recently revealed a close relationship to chemically obtained data (CONCANNON et coll. 1964).

Since chlorjodpropyl ^{131}I inulin became available SCHMIDT (1964) succeeded in establishing experimental base lines of its kinetics and distribution pattern in rats. This gave rise to the question whether radio inulin clearance could replace conventional chemical methods in man. The comparative clinical data presented in this paper support this view.

Methods

The *infusion solution* consisted of a mixture of

50 ml non radioactive inulin (10 % solution sterile, free of pyrogene)

75 µCi chlorjodpropyl ^{131}I inulin (from Farbwerke Hoechst Frankfurt Main) (isotonic solution sterile free of pyrogene pH = 5.0) specific activity 223 µCi/ml respectively 11.1 µCi/mg

500 ml NaCl solution (0.9 %)

The *technical equipment* consisted of a Twin Prober (Picker) with four channels for recording the activity with four wide angle collimators over the heart, bladder and both kidneys at 10 000 counts/min, time constant between 1—3 sec and chart speed 6-inch/hour.

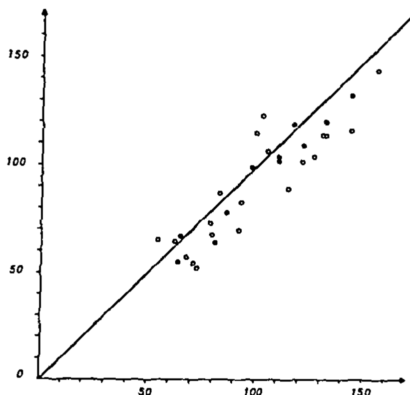


Fig. 1. Along ordinate: C_{In} ^{131}I; along abscissa: C_{Inulin}, both in ml/min//1.73 m^2. The filtration values of the chemical clearance (C_{In}) and isotopic clearance (C_{In} ^{131}I) determinations are indicated by the circles and the average filtration values calculated from 2—3 clearance periods are indicated by the filled circles.

Nuclear methods were developed in an effort to circumvent the problems inherent in conventional clearance procedures. A number of labelled substances have been tested in order to simplify conventional clearance determinations of glomerular function, i.e. ^{131}I Urografin, and, respectively, ^{131}I Hypaque (ref. 4 to 7, 49, 50), ^{131}I Hippuran (ref. 14, 52), ^{197}Hg Neohydrin (ref. 25), and labelled vitamin B 12 (ref. 32).

Some of these substances account for considerable extrarenal distribution and thus present a potential source of error in the calculation of filtration rates. So, since its first introduction in 1935 (SHANNON & SMITH), inulin remains the clearance substance of choice. — Similar properties seem to be attributed to polyfructosan S, as recently shown (MERTZ & SARRE 1963, WATSCHINGER & KOBINGER 1964). Inulin was first labelled with ^{14}C carboxyl. The beta activity of this isotope necessitates a special laboratory equipment with a liquid scintillation counter (COTLOVE 1955), also, the radiation hazards

Table 1

Patient	Urine flow (ml/min)				Clearance (ml/min/1.73 m²)			
	1	2	3	Average	^{125}I inulin A	Inulin B	Difference (ml/min) A—B	Quotient ^{125}I inulin/inulin A/B
	(Clearance periods)							
1	0.85	0.89	0.81	0.85	65.2	65.0	+ 0.2	1.003
2	1.20	2.26	3.49	2.36	54.0	63.3	− 9.3	0.85
3	7.70	2.25	6.55	5.50	103.0	109.8	− 6.8	0.94
4	0.27	0.33	0.40	0.33	109.0	121.3	− 12.3	0.90
5	5.03	6.05	7.31	6.13	118.7	116.5	+ 2.2	1.02
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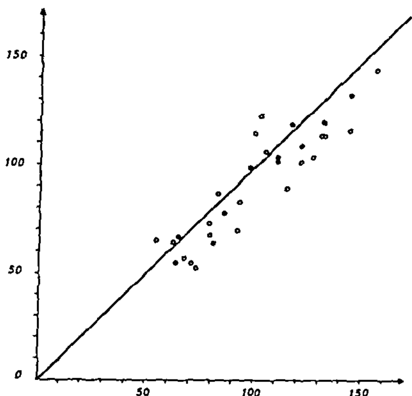


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Results

Simultaneous determination of the glomerular filtration rate using ^{131}I inulin and non radioactive inulin reveals close correlation between both groups (Fig 1 and Table 1) Filtration values range from 54 0 ml/min to 143 0 ml/min with an average clearance ratio ^{131}I inulin/inulin of about 0 94 The clearance of ^{131}I inulin averaged 5 9 ml/min, less than the corresponding inactive inulin clearance (Table 1)

Comparisons between the isotopic determination of ^{131}I inulin (counts/min) and the chemical concentration of inactive inulin (colorimetric extinction), in 19 blood samples of several periods bear out minor fluctuations in each patient when using the radioisotope assay (Fig 2) — *Alterations of* ^{131}I inulin/inulin content within each blood sample were expressed in terms of the percentage divergence from the initial inulin content of the first clearance period

No correlation could be established between the urine flow rates and the clearance values of either group

The mean of the thyroid ^{131}I uptake after 24 hours was about 9 %, with a maximum uptake of 14 % and a minimum uptake of 4 % (Table 2)

The authors could not detect any dependence on age of the thyroid radio odine uptake from the radio inulin

Discussion

The findings bear out that a close correlation between clearance values of the isotope procedure and the chemical method exists also in man The clearance ratio ^{131}I inulin/inulin = 0 94 indicates that the values of the isotope determination on the average seem to be below the chemical ones although there is no statistical difference between filtration data of both methods as previously reported (HEINZE et coll 1965) Similar results were observed by other authors with radio Hypaque (BURBANK et coll 1963) which is considered to share a common renal pathway with inulin It was stated that the clearances of ^{131}I Hypaque averaged only 2 2 ml/min/1 73 m² less than the simultaneous clearances of inulin whereas the clearance of ^{131}I inulin in the present investigations averaged 5 9 ml/min/1 73 m² less (maximum — 17 3 ml/min minimum + 0 2 ml/min) STOKES et coll (1963 1964) found the clearance of diatrizoate to be below that of inulin *and concluded that* it is reabsorbed by the tubules It would appear to the present authors that the higher results of the chemical colorimetric method could be partly ascribed to uncertainties inherent in this procedure

In outweighing the advantages of compounds tagged with gamma emitting

Table 2

Uptake of ^{131}I by the thyroid in eight patients examined by ^{131}I inulin after different deposition times of the ^{131}I Inulin charges

Age (in days) of undiluted ^{131}I inulin solution	3	4	5	6	9	10	12	15
Per cent thyroid uptake of ^{131}I after 24 hrs of ^{131}I Inulin of applied activity	4.8	14.1	6.8	10.1	5.9	4.1	12.7	12.3

For the *chemical method* determination of non radioactive inulin, the colorimetric (photometric) procedure described by FUHR et coll. (1955) was employed.

Clearance measurements. A 20 ml mixture of radioactive and non radioactive inulin were given intravenously, 30 ml were infused immediately (see above subheading 'infusion solution'), with an infusion rate of 4 ml/min.

After an equilibration time of 20—40 min, the activity over the heart and kidneys proved to be constant. Blood samples were drawn from a vein at intervals of 20 min (in the middle of each clearance period), 3—4 urine samples were collected every 20 min interval.

Quantitative emptying of the bladder was achieved under air-perfusion conditions by means of a 3 way catheter. Filtration values were calculated as average data from 2—3 clearance periods, each being compared with the corresponding value obtained by the chemical method (Fig. 1, and Table 1). A comparative determination of the clearance values was made according to the formula

$$C_{In} = \frac{U \cdot V}{P}$$

where

U = mg inulin/ml or counts/min/ml urine
V = ml/min urine flow
P = mg inulin/ml or counts per min/ml plasma

All values were referred to a standard body surface (1.73 m²). The patients were between 14 and 65 years of age and consisted of an unselected group with normal and impaired kidney function (Table 1).

Thyroid ^{131}I uptake. This was measured 24 hours after clearance in eight patients and calculated as a percentage of the activity applied (Table 2).

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Comparisons between the isotopic determination of ^{131}I inulin (counts/min) and the chemical concentration of inactive inulin (colorimetric extinction) in 19 blood samples of several periods, bear out minor fluctuations in each patient when using the radioisotope assay (Fig 2) — Alterations of ^{131}I inulin/inulin content within each blood sample were expressed in terms of the percentage divergence from the initial inulin content of the first clearance period

No correlation could be established between the urine flow rates and the clearance values of either group

The mean of the thyroid ^{131}I uptake after 24 hours was about 9 % with a maximum uptake of 14 % and a minimum uptake of 4 % (Table 2)

The authors could not detect any dependence on age of the thyroid radioiodine uptake from the radio inulin

Discussion

The findings bear out that a close correlation between clearance values of the isotope procedure and the chemical method exists also in man The clearance ratio ^{131}I inulin/inulin = 0 94 indicates that the values of the isotope determination on the average seem to be below the chemical ones although there is no statistical difference between filtration data of both methods as previously reported (HEINZE et coll 1965) Similar results were observed by other authors with radio Hypaque (BURBANK et coll 1963) which is considered to share a common renal pathway with inulin It was stated that the clearances of ^{131}I Hypaque averaged only 2 2 ml/min/1 73 m² less than the simultaneous clearances of inulin whereas the clearance of ^{131}I inulin in the present investigations averaged 5 9 ml/min/1 73 m² less (maximum − 17 3 ml/min minimum + 0 2 ml/min) STOKES et coll (1963, 1964) found the clearance of diatrizoate to be below that of inulin and concluded that it is reabsorbed by the tubules It would appear to the present authors that the higher results of the chemical colorimetric method could be partly ascribed to uncertainties inherent in this procedure

In outweighing the advantages of compounds tagged with gamma emitting

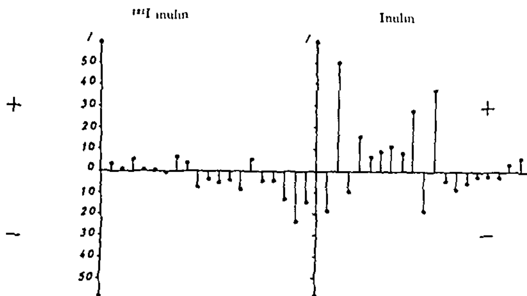


Fig. 2. Percentage deviations of inulin concentrations in singular blood samples of 19 clearance periods in relation to the initial values of the first clearance period.

isotopes we would say that isotope techniques are highly simplified and more accurate, as detailed comparisons have demonstrated (Fig. 2). In addition, the equilibration of the infusion solution in the organism, as a prerequisite of the quantitative clearance performance as well as the quantitative emptying of the bladder, may be accurately controlled by external measurement of the blood activity over the heart. Another attractive feature of the nuclear method lies in the possibility of referring to the value of only one blood sample for all the clearance periods by an adjustment of the surface counter and the well counter (STEINHOFF et coll. to be publ. in Nucl. Med.).

One of the disadvantages of the isotope procedure is the inevitable dissociation of ^{131}I that occurs in the blood, up to 6 % after 3 hours. With the solution kept under a pH of 6, the separation of ^{131}I is negligible (5 % after 30 days). The present authors calculated an average content of free ^{131}I of about 15 % in the body, which is little below the results of CONCANNON et coll. (1964) (20 % to 30 %) after infusion of a freshly prepared ^{125}I allyl inulin solution in dogs. The separation of ^{131}I and a possible tubular reabsorption of the anion, could be causative factors for the divergence of the filtration values in these comparative examinations.

As outlined in the preliminary report (HEINZE et coll. 1965), we could detect no vital dependence of thyroid ^{131}I uptake on the ageing of radio-inulin, such as other authors did (CONCANNON et coll. 1964). The highest initial ^{131}I uptake by the thyroid has been measured after a 4 day deposition

of radio inulin (14 %) of the activity administered and the lowest one (4 %) after using a 10 day old charge

Nevertheless complete removal of free ^{131}I in the infusion solution may improve the correlations between the chemical procedure and the isotope determination in a still higher degree CONCANNON et coll for instance separated loosely bound ^{131}I by repeated passage of the solution through ion resin exchange columns

Conclusions

Close correlations between classical inulin and radio inulin clearance support the view that the isotope procedure may replace the often inaccurate time consuming chemical determinations A clearance ratio of ^{131}I inulin/inulin = 0 94 with an average deviation of ^{131}I inulin clearance from 5 9 ml/min less than the conventional clearance appears to be within acceptable limits The results suggest that ^{131}I inulin may be recommended for use in man in the determination of the glomerular filtration rate because it seems to be excreted by the kidneys in the same manner as non radioactive inulin The authors would emphasise that isotope clearances should also be performed under standard conditions (ref 7 24 29 33) All attempts to simplify standard procedures by a single injection technique (ref 4 5 49) meet with the inconstancy of renal clearance on account of the changing plasma concentration (ref 9 33 38)

It is obvious that by the differential labelling of renal clearance substances (^{131}I inulin ^{125}I Hippuran) the isotope technique lends itself to the simultaneous determination of the glomerular filtration rate and the renal blood flow in a simple way (ref 7 29 42 43, 49)

SUMMARY

A comparison between chemical inulin and nuclear inulin procedures to determine glomerular function has demonstrated that the latter are now practicable as well as preferable The value of the differential labelling of certain renal clearance substances is discussed

ZUSAMMENFASSUNG

Inulin und radio-aktives Inulin wurden zur Untersuchung der Glomerulusausscheidung verwendet Es erwies sich dass das radio aktive Inulin praktisch benutzbar und vorzuziehen ist Der Vorteil der unterschiedlichen Markierung gewisser Substanzen fur die Untersuchung der Nierenausscheidung wird besprochen

RÉSUMÉ

Une étude comparative de la *détermination des fonctions* glomérulaires par l inuline chimique et par l inuline marquée avec un corps radio actif a montré que celle ci est utilisable et même préférable A ce propos les auteurs examinent l intéret du marquage différentiel de certaines substances à clearance rénale

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RÉSUMÉ

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR PROF E. LINDGREN) ERAFIMER LASARETTET STOCKHOLM SWEDEN

CASSETTE FOR SIMULTANEOUS MULTIPLANE TOMOGRAPHY WITH NON SCREEN FILM

by

OLVE MATTSSON

Non-screen film has not been much employed in tomography although ...son (1953) described a non screen cassette There are several reasons for ... the main one being that non screen film has a much lower sensitivity ... a screen film combination The contrast conditions to some extent have been unfavourable since tomograms being recordings of thin anatomic ... generally contain small contrast differences The high resolution of ...screen film has not been found necessary in conventional tomography ...gh definition in modern tomography is possible Small objects such as ...etal parts of the skeleton are preferably examined with non screen ...en conventional roentgenog... film is employed Simultaneous multiplane ...aphy may however easily ... rformed with such film All problems ...ed with the varying d... of intensification needed in different because of roentgen ra... ...n in screens can be excluded and the ...on of the non-screen fi... ...ay be neglected ...al cassette has there... ...nstructed In this the film is arranged ...he ordinary envelo... ...rd sheet so that secondary radiation

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR PROF E LINDGREN) ERAFIMER
LASARETTET STOCKHOLM SWEDEN

CASSETTE FOR SIMULTANEOUS MULTIPLANE TOMOGRAPHY WITH NON SCREEN FILM

by

OVE MATTSSON

Non screen film has not been much employed in tomography, although WATSON (1953) described a non screen cassette There are several reasons for this the main one being that non screen film has a much lower sensitivity than a screen film combination The contrast conditions to some extent have also been unfavourable since tomograms being recordings of thin anatomic layers generally contain small contrast differences The high resolution of non screen film has not been found necessary in conventional tomography

High definition in modern tomography is possible Small objects such as peripheral parts of the skeleton are preferably examined with non screen film when conventional roentgenography is employed Simultaneous multiplane tomography may however easily be performed with such film All problems connected with the varying degrees of intensification needed in different planes because of roentgen ray absorbtion in screens can be excluded and the ab orbtion of the non screen film itself may be neglected

A special cassette has therefore been constructed In this the film is arranged without the ordinary envelope or cardboard sheet so that secondary radiation

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Fig 1 The special cassette for non screen film tomography with films inserted along tracks on each side

is avoided The films are taken out of their wrappings and placed in the cassette uncovered The cassette is made of light metal and has tracks on two sides of the interior The films are inserted in such a manner that they become self supporting Fig 1 shows a cassette unlocked with five films, 9 × 12 cm in size, spaced at 2 5 mm intervals It should be stressed that conventional roentgen film, supplied for use with screens, is not suitable as it produces

Fig 2 *Top row* Normal tomograms of the scaphoid *Bottom row* Tomograms showing pseudoarthrosis of the scaphoid



Fig 3 Tomograms (left) and con entional roentgenogram (right included for compa i on) in a cas of f actu e of the distal part of the radius

too low a contrast for tomography The practical application is obvious Ordinarily only two exposures are needed to cover the bones of the wrist

A few examples of tomograms obtained with the new multiplane cassette are presented in Figs 2 and 3 Tomograms of a normal scaphoid bone are given in Fig 2 (upper row) and pseudoarthrosis of the bone demonstrated in Fig 2 (lower row) A fracture of the distal part of the radius is evident in the tomograms of Fig 3 a conventional roentgenogram is included for comparison

The cassette which was mainly intended for the Mimer I and II may be employed equally well with most tomographic equipment

SUMMARY

A cassette for simultaneous multiplane tomography of small objects is presented Non s reen film is util zed and the cassette which can be u ed with most equipments has proved to be valuable for examining the skeleton

ZUSAMMENFASSUNG

Eine neue Kassette wird angegeben die es ermoglicht Simultanschnitte in mehreren Schichten an kleinen Objekten vorzunehmen Film ohne Verstarkungsfolien wird benutzt die Kassette kann mit verschiedenen Tomographieapparaten angewandt werden Die Methode ist fur die Tomographie des Knochengerustes besonders wertvoll

RÉSUMÉ

Présentation d une cassette pour la tomographie simultanée de plusieurs plans pour de petits objects On utilise des films sans écrans cette cassette peut etre utilisée avec la plupart des appare ls et s est montree interessante pour l examen du squelette

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